JOURNAL
OF THE
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MAY 1930

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PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

NORTH EASTERN DISTRICT MEETING No. 1, Springfield, Mass., May 7-10, 1930

SUMMER CONVENTION, Toronto, Ontario, Canada, June 23-27, 1930

PACIFIC COAST CONVENTION, Portland, Oregon, September 2-5, 1930

MIDDLE EASTERN DISTRICT MEETING, No. 2, Philadelphia, Pa., October 13-15, 1930

SOUTHERN DISTRICT MEETING, No. 4, Louisville, Kentucky, November 19-22, 1930

MEETINGS OF OTHER SOCIETIES

National Electric Light Association

Southwestern Division, Hot Springs, Ark., May 6-9. (S. J. Ballinger, San Antonio Public Service, San Antonio, Tex.)

East Central Division, Hotel Statler, Cleveland, May 20-23. (D. L. Gaskill, Greenville, Ohio)

Pacific Coast Division, San Francisco, Calif., June 16-20. (S. H. Taylor, 447 Sutter St., San Francisco)

San Francisco, June 16-20. (A. J. Marshall, 420 Lexington Avenue, New York)

American Electrochemical Society, St. Louis, Mo., May 29-31. (C. G. Fink, Columbia University, New York)

Spring Meeting American Society of Mechanical Engineers, Detroit, June 9-12. (Calvin W. Rice, Secretary, 29 West 39th St., New York, N. Y.)

Canadian Electrical Association, Manor Richelieu, Murray Bay, Que., June 11-13. (M. H. Lyster, 405 Power Building, Montreal)

American Electric Railway Association, San Francisco, June 21-26. (Guy C. Hecker, 292 Madison Ave., New York)

American Society for Testing Materials, Haddon Hall, Atlantic City, N. J., June 23-27. (C. L. Warwick, 1315 Spruce St., Philadelphia)

JOURNAL of the A. I. E. E.

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York
PUBLICATION COMMITTEE
W. S. Gorsuch, *Chairman*, H. P. Charlesworth, F. L. Hutchinson, A. E. Knowlton, E. B. Meyer

George R. Metcalf, *Editor*

Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.
Subscription: $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines, $10.50 to Canada, Central America, South America, Haiti, Spain and Colonies, and $11.00 to all other countries.
Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

Vol. XLIX — MAY 1930 — Number 5

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A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address, be sure to mention the old one, indicating also any changes in business connections.

American Institute of Electrical Engineers

—*Some Activities and Services Open to Members*—

The Pacific Coast Conventions as their name implies are always held in the Pacific Coast States or British Columbia, and were inaugurated for the benefit of Western members who by reason of their location could not conveniently attend the conventions held in the eastern part of the country. The engineering problems encountered in the West have also been different to some extent from these in the East owing to the very long-distance high-voltage transmission systems which are characteristic of the Pacific Coast region. The programs of these conventions cover all phases of electrical engineering but accentuate those features which are of peculiar interest to western engineers. Social and entertainment features are always included, as well as inspection trips of special interest to visitors from a distance.

Attendance at Conventions.—Taking part in the Institute conventions is one of the most useful and helpful activities which membership in the Institute affords. The advantages offered lie in two distinct channels; technical information and personal contacts. The papers presented are largely upon current problems and new developments, and the educational advantages of hearing and taking part in the discussion of these subjects in an open forum cannot but broaden the vision and augment the general knowledge of those who participate. Equally advantageous is the opportunity which conventions afford to extend professional acquaintances and to gain the inspiration which grows out of intimate contact with the leaders in electrical engineering. These conventions draw an attendance of from 1000 to 2000 people and constitute milestones in the development of the electrical art.

To Members Going Abroad.—Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for a period of three months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York. The members should specify which country or countries they expect to visit, so that the proper number of certificates may be provided, one certificate being addressed to only one society.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Societie Francaise des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Norsk Elektroteknisk Forening (Norway), Svenska Teknologforeningen (Sweden), Elektrotechnicky Svaz Ceskoslovensky (Czechslovakia), The Institution of Engineers, Australia (Australia), Denki Gakkwai (Japan), and South African Institute of Electrical Engineers (South Africa).

Library Service.—The Engineering Societies Library is the joint property of the four national societies of Civil, Mining, Mechanical, and Electrical Engineers and comprises one of the most complete technical libraries in existence. Arrangements have been made to place the resources of the library at the disposal of Institute members, wherever located. Books are rented for limited periods, bibliographies prepared on request, copies and translations of articles furnished, etc., at charges which merely cover the cost of the service. The Director of the library will gladly give any information requested as to the scope and cost of any desired service. The library is open from 9 a. m. to 10 p. m. every day except holidays and during July and August, when it closes at 5 p. m.

JOURNAL OF THE A. I. E. E.

Devoted to the Advancement of the Theory and Practise of Electrical Engineering and the Allied Arts and Sciences

Vol. XLIX MAY, 1930 Number 5

A Message From the President

THE BADGE OF THE INSTITUTE

A RECENT visit to most of the Sections of the Institute developed the fact that a large proportion of the members of the Institute were not familiar with the history and development of the present badge of the Institute. The story of the badge, as closely as it was then known, was told on several occasions and appeared to arouse considerable interest. It has since been examined more carefully and, subject to revision if necessary, deserves a more permanent recognition.

Oct. 21st, 1890, the Council of the American Institute of Electrical Engineers "on motion of Dr. S. S. Wheeler, voted that the Secretary be instructed to secure a design for a badge and present the same to Council."

Dec. 16th, 1890, on motion of Dr. Wheeler, it was voted that the design for a badge be laid upon the table." On Oct. 27th, 1891, on motion of Dr. Herzog, a committee of three, Messrs. Herzog, Bell and Foster, was appointed by the Chair to examine into the propriety of issuing a certificate for the different classes of membership. A "letter was read from Mr. F. L. Woodward, enclosing a sample of a society pin." On motion of Mr. W. J. Hammer it was voted that the letter and sample be referred to the committee on certificate of membership, and that members generally be invited to contribute competitive designs." On Oct. 27th, 1891 the committee asked for advice and was continued with the understanding that further designs should be secured. Feb. 16, 1892, Dr. Bell of the committee submitted several designs which were examined. On motion of Prof. Compton, it was voted that the committee be instructed to prepare new designs embodying as principal features the Kite and the electromagnet, with the initials of the Institute. Progress reports of the Committee were presented at various Council meetings until, at a meeting of Feb. 21, 1893, "on motion of Prof. Compton, it was voted that the design for a badge presented by the committee be accepted and that the design be adopted as the badge of the Institute. It was also voted that the design of the badge be placed upon the certificate and the literature and stationery of the Institute."

The above is a story of the old original badge which appeared on the front cover of the monthly TRANSACTIONS of the Institute from August 1893 to April 1897, and was worn by the members during those years. It was of gold, with a plain white enamel surface for the "Kite."

At a meeting of the Council, Nov. 20, 1895, a petition signed by 20 members was read, asking that steps be taken to secure a better design. A committee was appointed, Messrs. W. J. Hammer, W. D. Weaver, M. I. Pupin, W. A. Anthony and S. S. Wheeler, which made a final report March 24th, 1897 "with designs and a sample" which was referred to the annual meeting for consideration. The report of the annual business meeting of May 18, 1897 included "At the conclusion of the discussion . . . . the matter of the design reported by the committee was adopted. (See design on cover.)" This emblem has held a prominent place in Institute publication since that date. In a letter of Oct. 20th, 1914, by Dr. S. S. Wheeler, Chairman of Committee, on which action was taken, states the design was chosen "after considerable thought as a symbol of the broadest principle that could be found underlying our profession, electricity always surrounds magnetism and magnetism always surrounds electricity and each forms a closed circuit; therefore the relation between them is always that of two closed links which pass through each other, and this holds true of course in every application of electricity or magnetism."

Benjamin Franklin's letter of Oct. 19, 1752, to his friend, Peter Collinson, pp. 117-118 "Experiments and Observations on Electricity" relates:- "Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large thin silk handkerchief when extended: . . . . but this being of silk is fitter to bear the wet and wind of a thunder gust without tearing." . . . . and thereby the sameness of the electric matter with that of lightning completely demonstrated."

Harold B. Smith
President.

Some Leaders of the A. I. E. E.

John Castlereagh Parker, Vice-President in charge of Engineering, Brooklyn Edison Company, Inc., Associate Member of the Institute 1904, Fellow 1912, and Vice-President 1920-21, was born in Detroit, Michigan, April 15, 1879. In 1901 he was graduated with the degree of B. S. in M. E. at the University of Michigan receiving his A. M. there in 1902 for advanced work in mathematics, physics and structural engineering. In 1904 the university granted him an E. E. for work done *in absentia,* his dissertation being "A Physical Concept of Dynamo Electric Machines."

At the end of his graduate year in residence he was employed as a tester in the works of the General Electric Company at Schenectady and during the academic year 1903-1904, was an Instructor in Union University under Doctor Steinmetz, giving at the same time a course in thermodynamics and another in the Mathematics Department. Returning to industrial work in 1904, he spent a year as Assistant to the Engineer-in-Charge of the Construction and Design of the Ontario Power Company's Plant at Niagara Falls, Ontario, at that time the largest hydroelectric undertaking. In addition to the routine work of the office, the position covered special mathematical and experimental investigations of hydraulic, structural, and electrical matters.

In 1905, on the completion of the first section of the Ontario Power Company's plant, he went to Buffalo as Assistant to the late F. B. H. Paine, Vice-President and Chief Engineer of the Construction Company building the lines of the Niagara, Lockport, and Ontario Power Company from Niagara Falls to Syracuse, the first 60,000-volt transmission, on which Ralph D. Mershon, Fellow and Past-President of the Institute, did the engineering.

In 1905, with the introduction of Niagara Power into Rochester, he removed to that city and shortly became Mechanical and Electrical Engineer of the Rochester Railway & Light Company, in charge of the hydraulic, structural, steam and electrical engineering and construction of the company's electric properties. to the engineering work was added shortly the organization of the Power Sales Engineering Division and the formulation of the company's electric rate schedules.

During this period and during the ensuing seven years he was also engaged in various consulting enterprises of an electric and hydraulic character.

In 1915 the University of Michigan made him Professor of Electrical Engineering in charge of the Department, from which position he resigned in 1922 to become Electrical Engineer of Brooklyn Edison Company, Inc., at the beginning of the design of Hudson Avenue Generating Station. The initial portion of this station was constructed during his incumbency of the position of Electrical Engineer and in the same period of the program of Brooklyn Edison Company of gradually retiring its direct current was initiated together with the change of its distribution system from two-phase to three-phase and the development of its 27,000-volt ring transmission system.

In 1926 he became Vice-President in Charge of Engineering of Brooklyn Edison Company, his present position, a principal work of which is the cooperation with other engineers of the New York Edison System in the unification of the engineering and construction processes of that system's group of companies.

While primarily interested in higher mathematics and physics during the more active portions of his professional career, he has shifted the emphasis to a consideration of engineering as a technical branch of applied economics and more recently has become especially interested in the practical aspects of standardization and simplification of production, design, and construction.

In this latter interest, he is at present serving as Chairman of the Institute's Delegation to American Standards Association.

Mr. Parker's own appraisal of his two educational excursions is that all administrative work is necessarily somewhat educational in its character and therefore naturally leads into the more obvious educational field, while, on the other hand, the experience as an educator should help in the cooperative relations of organized industry.

Mr. Parker is a member of the American Society of Civil Engineers and The American Society of Mechanical Engineers, the Engineers Club, the Crescent Athletic Club, the Downtown Athletic Club, and the Huntington Bay Club.

Outside these professional activities his chief interests lie in an attempt at old fashioned family life in companionship with Mrs. Parker and their three children; amateur attempts at architectural design and landscape gardening, which latter interests, in their more active expressions, he pursues at his country home at Huntington, Long Island, while the atmosphere of Brooklyn, his principal residence, conduces to the former.

Water Power Increases over 1928

According to the report of the Division of Water Resources, U. S. Geological Survey, Department of Interior, compiled by A. H. Horton, there was produced during 1929 from water power more than 97 billion kilowatt-hours. This was an average increase of 11 per cent over 1928 and represented 36 per cent of the total power produced. That produced in January, 1930, was over 8 billion kilowatt-hours, and represents an increase of 5 per cent over January, 1929.

A Self-Compensating Temperature Indicator

BY I. F. KINNARD[1] and H. T. FAUS[1]

Member, A. I. E. E. Associate, A. I. E. E.

Synopsis.—The following paper describes a unique adaptation of the temperature sensitive magnetic alloys known as "calmaloy" to the cold junction compensation of thermocouple temperature indicators. It has been known for some time that certain specially prepared copper-nickel alloys possess the property of changing permeability linearly with temperature over very wide ranges. This peculiar function of permeability has been advantageously used for effecting temperature compensation on different devices, particularly watthour meters. The need has recently arisen of providing suitable compensation for millivolt meters used in connection with thermocouples for determining the temperatures of air cooled aircraft motors. It is shown that by employing the restoring torque on the instrument produced by a small vane of calmaloy in addition to the usual restoring torque of the spring, a very satisfactory compensation results. Curves are shown which illustrate the accuracy of compensation obtained and a detailed explanation of just how it is accomplished is also given.

* * * * *

THE development of air-cooled airplane motors, in which the operative temperatures are rather high as compared with those of water-cooled motors, has made it expedient to find means of measuring these temperatures. For laboratory measurements where the weight and cost of apparatus are not important, and where high accuracy is desirable, the type of pyrometer utilizing a thermocouple and a potentiometer has proved very useful. For permanent installation on an airplane where a direct reading instrument of fairly small size is required, it has been the practise to use a millivoltmeter with an iron-constantan thermocouple, the cold junction being made at the instrument. A mercury thermometer is used to indicate the cold junction temperature. This method has the very serious disadvantage of requiring calculation to determine the temperature of the hot junction.

Various methods of cold junction compensation are successfully used on thermocouple type pyrometers now on the market. In general, they may be divided into two types, electrical and mechanical. The former type uses an e. m. f. derived from a battery and an adjustable portion of this e. m. f. is added to the thermocouple e. m. f. to correct for the change due to the difference between the actual cold junction temperature and that for which the instrument was calibrated. The latter type uses a bi-metallic spring which, for a given change in temperature, will move the pointer by an amount sufficient to compensate for the error caused by the change in cold junction temperature.

The battery method is not considered suitable for aircraft use on account of the weight, and because of the effect of very low temperature on the e. m. f. of the battery. Since the instrument should have a scale range from 100 to 650 deg. fahr., and should give reasonably accurate readings at any cold junction temperature from + 105 to − 40 deg. fahr., it was believed that it would not be practicable to use a bi-metallic spring capable of supplying a correction equal to 27 per cent of the full scale reading of the instrument. This problem is made much more difficult by the small size of the instrument required.

In a previous article, mention was made of a series of temperature sensitive magnetic alloys.[2] These alloys have been manufactured for some years under careful control for use in meters and instruments. Some

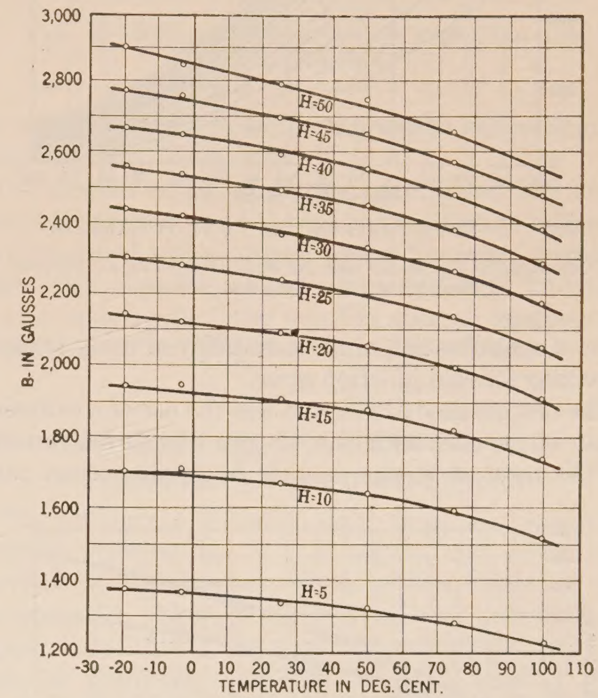

FIG. 1—FLUX TEMPERATURE TESTS ON CALMALOY

Composition: Cu 9.5 per cent, Ni. 88 per cent, Fe. 2.2 per cent
Heat Treatment: Quenched in water

hitherto unpublished data on these materials are shown in Figs. 1, 2, and 3. Figs. 1 and 2 show that the permeability and point of magnetic transformation are increased with decreasing copper content and that this

1. General Electric Company, West Lynn, Mass.

Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Printed complete herein.

2. *Temperature Errors in Induction Watthour Meters*, A. I. E. E. TRANS., Vol. XLIV, 1925, p. 275. In this paper, the name "thermalloy" was applied to these alloys, but it was subsequently learned that this name had previously been applied to a heat resisting alloy. Hence, the name of this series of temperature sensitive magnetic alloys has been changed to "calmaloy," which is derived from caloric magnetic alloy.

change is accompanied by a decrease in the slopes of the temperature-flux curves. Fig. 3 shows that quenching gives a lower permeability than is obtained when the material is cooled slowly, but that the hysteresis is much less in the quenched material. Since low hysteresis is essential in these materials, the quenching treatment is used. The success which has attended their use in correcting other types of temperature errors

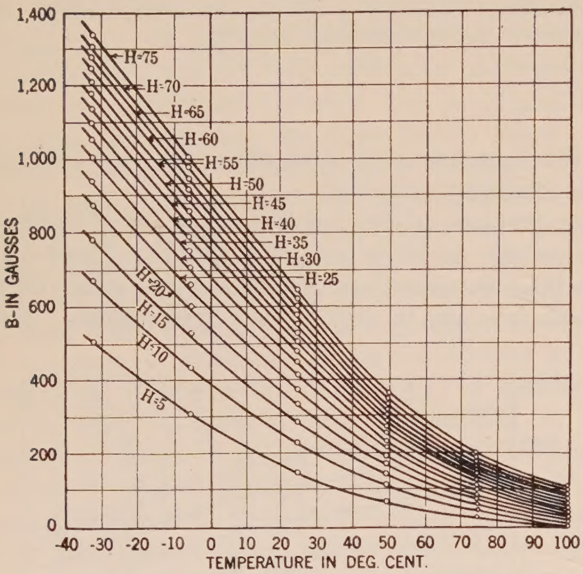

Fig. 2—Flux Temperature Tests on Calmaloy

Composition: Cu. 30 per cent. Ni. 66.5 per cent, Fe. 2.2 per cent
Heat Treatment: Quenched in water

led to a consideration of the possibility of using them in correcting for cold junction error.

The first method attempted was the use of a calmaloy shunt in parallel with the air-gap of the instrument. By this method, it was possible to obtain correct com-

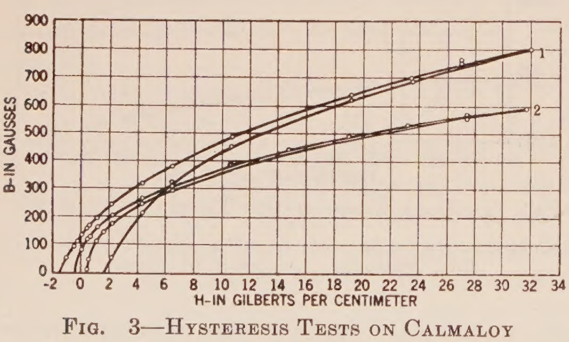

Fig. 3—Hysteresis Tests on Calmaloy

Composition Cu. 30 per cent, Ni. 66.5 per cent, Fe. 2.2% per cent
1. Cooled slowly in furnace
2. Quenched in water

pensation at only one point on the instrument scale since the correction supplied by the shunt was proportional to the scale reading, while the cold junction error was the same at all points in the scale. Fig. 4 illustrates the results which would be obtained if an instrument were correctly compensated for cold junction temperature variation at 70 per cent of full scale reading. It is evident that this method of compensation is suitable only for purposes requiring accuracy over a very narrow hot junction temperature range.

Since it is necessary to measure the temperature of the cylinder wall which should not exceed 310 deg. fahr. and the temperature of the cylinder head, which may be as high as 600 deg. fahr., and it is also desirable to use one instrument with two thermocouples and a selector switch for taking both measurements, it is evident that the type of compensation just described is not suitable for use in measuring engine temperatures. What is required is a compensation that will be effective over the entire range of the scale.

The required type of compensation was obtained by mounting a calmaloy vane on the instrument armature in such a relation to an auxiliary pole piece that the magnetic attraction between the vane and the pole piece produces a torque tending to move the instrument pointer toward the lower end of the scale. When the temperature of the instrument is lowered, the per-

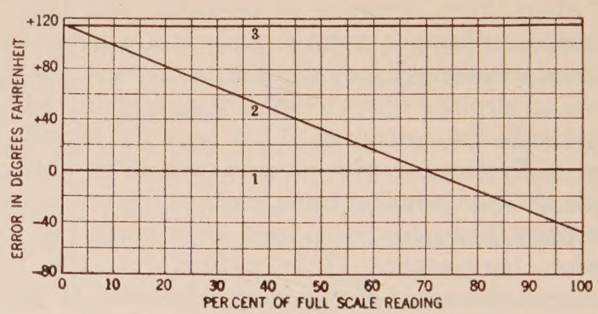

Fig. 4—Cold Junction Compensation Obtained by use of a Calmaloy Shunt

1. Calibration at 75 deg. fahr.
2. Calibration of compensated instrument at − 40 deg. fahr.
3. Calibration of uncompensated instrument at − 40 deg. fahr.

meability of the calmaloy vane is increased, thus causing it to exert a stronger torque; this balances the increase in torque due to the increase in millivolts due to the lowering of the cold junction temperature. Since both effects have a linear variation with temperature, a good compensation may be obtained over a wide range of cold junction temperatures.

It is the usual practise to connect a sufficient amount of manganin or other resistance wire having a low temperature coefficient in series with the armature of a millivoltmeter to minimize resistance changes due to changes in the temperature of the copper windings. It is evident that this is not a very desirable method to use in a case where only a very small amount of electrical energy is available for the operation of the instrument, since the sensitivity is reduced in the same proportion as is the temperature error.

The temperature error due to the change in resistance of the windings is proportional to the scale readings and hence could be perfectly compensated by a temperature sensitive magnetic shunt similar to that described in connection with the cold junction compensation. Principally on account of the manufacturing difficulties

which would be caused by using both methods of compensation in the same instrument, it was decided to use the calmaloy vane to compensate for both the cold junction error and the error due to the change in the resistance of the instrument. This problem may be understood more easily by referring to Fig. 5. It will be noted that the curve representing the total error is the sum of two errors, one increasing with increasing scale deflection, and the other remaining the same for all points on the scale. It is necessary to provide a type of compensation which will increase with increasing deflection in the same manner as shown by the curve representing the total error. This is done by proportioning the magnetic circuit so that the rate of change of flux, and hence the torque, acting on the calmaloy vane is increased with increasing scale reading.

Fig. 6 illustrates the method of applying this compensation to a standard type d'Arsonval instrument. This instrument has a coil (*e*) of cylindrical section, iron pole pieces ($c\ c^1$) having inside surfaces of spherical section and a spherical iron core which, together with the springs, is omitted from the drawing in order to avoid confusion. The compensating pole piece (*b*) which is made of iron is mounted on the pole piece (*c*). The calmaloy vane (*a*) is mounted parallel to the armature shaft. The pole piece (c^1) is cut away as shown so that it will not exert an attraction which will oppose the attraction of the compensating pole piece for the calmaloy vane. The principal path of the flux which produces the compensating effect is indicated by

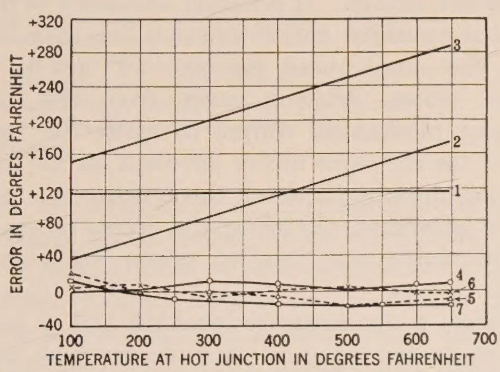

FIG. 5—RESULTS OBTAINED BY THE USE OF A CALMALOY VANE IN COMPENSATING FOR AMBIENT TEMPERATURE ERRORS IN THERMOCOUPLE TYPE TEMPERATURE INDICATORS

1. Error due to cold junction temperature at −40 deg. fahr.
2. Error due to change in instrument resistance at −40 deg. fahr.
3. Total error in uncompensated instruments at −40 deg. fahr.

4-7. Errors in compensated instruments at −40 deg. fahr. All instruments calibrated to read correctly at + 75 deg. fahr.

the arrows. It will be noted that the flux, after crossing the air-gap between the compensating pole piece and the calmaloy vane, passes through the coil and across a second air-gap to the core. The length of this second air-gap is not changed when the armature is rotated, but may be varied by raising or lowering the armature by means of the jewel screws. This provides a convenient means for adjusting the compensation.

Fig. 5 shows the results obtained on four instruments compensated by this method. Although it is possible to secure a very accurate compensation, the cost is materially increased if it is attempted to hold an accuracy of better than 20 deg. fahr. for a change in ambient temperature from + 75 to − 40 deg. fahr. This means that the error will be less than one-fifth of

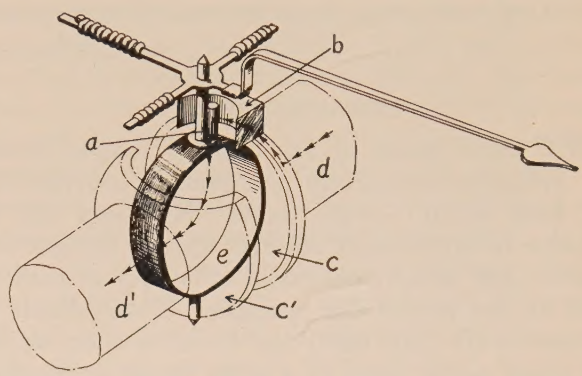

FIG. 6—D'ARSONVAL INSTRUMENT WITH CALMALOY COMPENSATION

the change in ambient temperature from the calibrating temperature of 75 deg. fahr.

On account of its simplicity, sturdiness, and small size, it is believed that the type of temperature indicator just described will be found useful for many purposes other than that for which it is particularly intended. It also appears that the possible uses of temperature sensitive magnetic alloys have not been exhausted.

ARTIFICIAL LIGHTING AND CONTINUOUS OPERATION

The work-place of today which does not have good artificial lighting is, in this respect, an antiquated survivor of yestercentury when artificial lighting was undeveloped. Now, artificial light need no longer be a poor substitute to be used when daylight fails. It costs no more than daylight and it is superior in a number of respects. It can be obtained when and where desired. It need seldom fail. It can be used effectively to supplement daylight, thereby making daytime operations in work-places safer and more efficient. It also makes possible multiple-shift or continuous operation.

Possessing all these and other characteristics, artificial lighting should be rescued from the class of expense items. It becomes worthy of the best attention. The design of an artificial-lighting system should be of the type dictated by its importance and possibilities. It should provide without glare the highest intensity of illumination economically justifiable. And it should be obvious that the lighting equipment and the reflecting surfaces upon which better lighting depends should be systematically maintained.—*Industrial Engineering.*

The Synchronous-Repulsion Motor

A Special Development for the Photophone

BY H. C. SPECHT*

Member, A. I. E. E.

Synopsis.—This paper describes a motor which is developed specially for the operation of photophone machinery. The characteristics of this motor are analyzed and demonstrated by oscillograms. Since the well-known theory of synchronous and repulsion motor can easily be applied for this double motor, no equations are given. For illustration of the characteristics various oscillograms and test curves are given.

* * * * *

Introduction

THE exact speed of an ordinary motion picture projector is relatively unimportant provided it is kept within certain limits. Not only can the projector be operated at different speeds, but also it is possible, and usually desirable, to be able to vary the speed at the will of the operator. These simple requirements are quite easily met by an ordinary adjustable speed motor, such as a series motor or repulsion motor with some form of speed control.

Such a motor, however, would be quite unsuitable for driving a talking motion picture projector. In the first place, the sound record, whether it be on the film itself or on a disk driven synchronously with the projector, must be run at one definite speed in order that the musical sounds be reproduced at their correct pitch. Even more important than the fact that the record be run at the proper speed is the fact that once the speed is set, it must not be changed suddenly, for while only a few may have an ear for "absolute pitch," practically every one experiences a disagreeable sensation if the pitch suddenly changes. However, these requirements are easily met by a synchronous motor for the frequency of a modern power system is substantially constant.

However, a synchronous motor is not entirely satisfactory, for sometimes a theater will have mixed into its program, the ordinary silent pictures. In order to keep performances on schedule, these silent pictures must often be run at a different speed,—usually higher,—and the adjustable speed characteristics desirable with the ordinary projector are highly desirable in this case, too. Thus, the application requirement for this service is a driving set which can be operated either as a synchronous motor when desired, or as an adjustable speed motor which speeds up to, say, one and one-half times synchronous speed. These requirements could be met by a synchronous motor and an adjustable speed repulsion motor on the same shaft, but limited space requirements in a projection booth and simplicity in operation make it highly desirable to have this dual service provided by a single machine. Such a machine, which may well be styled a synchronous-repulsion motor, has been developed for this service and will be described in this paper.

Suppose two separate motors, a synchronous motor and a repulsion motor mechanically coupled in tandem to drive an external load, and further suppose both machines to be connected to a proper source of power, an external resistance or other speed-controlling means being provided for the repulsion motor. The repulsion motor can be used to bring the load and synchronous motor up to synchronous speed where the set will pull into step and operate in synchronism, provided of course that the torque of the repulsion motor at synchronous speed is less than the break-down torque of the synchronous machine as a generator plus the load torque, and more than the difference between the load torque and the breakdown torque of the synchronous machine as a motor. It is hardly necessary to mention that if the repulsion motor torque is less than the load torque, the synchronous machine will act as a synchronous motor, drawing power from the line and developing mechanical torque to assist the repulsion motor; if the repulsion motor develops torque in excess of that required by the load, the synchronous machine acts as a generator, absorbing the excess torque of the repulsion motor and feeding power back into the line.

However, a synchronous machine and a repulsion motor can be combined into a single machine using the same magnetic circuit and the same windings. Such a motor is shown diagrammatically in Fig. 1.

When the switch *g* is thrown to the upper position, the machine will operate as an ordinary repulsion motor, speed control being effected by means of the rheostat *h*, though of course this could be done by control of the line voltage by means of a transformer, resistance or reactance in the line circuit, etc. When the switch *g* is thrown to its lower position, the motor, for reasons to be explained later, will come up to speed, pull into step and operate as a synchronous motor. A flywheel is provided to prevent hunting during synchronous operation. Thus, the control of this motor is so simple that an inexperienced person can readily operate it.

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Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Printed complete herein except for Bibliography.

Determination of the Size of Motor Required

As already mentioned, the projector must be run at speeds above synchronism. The power requirements at the highest speed fix the size of the motor for it can be designed as an ordinary repulsion motor, ample in size to carry this load at this speed as if there were no other considerations. The design of the motor being fixed, nothing remains to be determined except the direct current excitation necessary for satisfactory synchronous operation which can either be calculated or found experimentally.

Characteristics of the Synchronous Repulsion Motor

The characteristics of this motor are somewhat different from those of any conventional single machine, but closely resemble the characteristics of two machines in tandem as previously described.

It is generally known that when the slip-rings of such

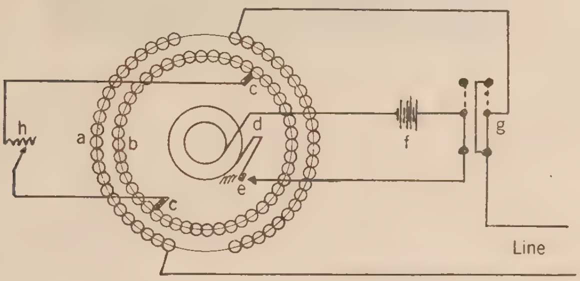

Fig. 1—Combined Synchronous and Repulsion Motor

a. Stator winding
b. Repulsion armature and d-c. exciting winding
c. Brushes on the commutator
d. Slip-rings and brushes on them
e. Centrifugal or automatic switch of some sort
f. Storage battery or other source of direct current
g. Double-pole, double-throw switch
h. Rheostat

a motor are short-circuited, the armature will run at synchronous speed under certain conditions. As the action of this motor is easier to understand if the latter be excited by direct current, let us consider this case. Since the direct current is introduced into the armature winding at two points which are fixed with respect to the armature, the direct current will set up magnetomotive forces tending to set up a flux which is fixed in space with respect to the armature; that is, the direct current sets up magnetic poles similar to the poles set up in a non-salient pole turbo alternator. These poles lock in with the rotating field set up by the repulsion motor and thus the armature rotates at synchronous speed.

Although the rotating member is excited from a direct current source, the exciting current and flux set up by the rotating member will pulsate strongly, mainly due to the high reaction of the a-c. field caused by the small air-gap, the low permeance of the laminated iron, and the distribution of the armature winding. The frequency of this pulsation is twice the line frequency, just as it is in an ordinary synchronous motor. A further pulsation is caused by a periodic short-circuiting of the slip-rings through the repulsion brushes. However, this effect is not very great since the contact resistance of the repulsion brushes is fairly high.

If the slip-rings be merely short-circuited, somewhat similar effects will be obtained, for the motor will run in synchronism with the line frequency under certain conditions and there will be pulsations of twice the line frequency in the slip-ring circuit due to having a winding rotating in the a-c. stator field. In this case, however, the effect is somewhat similar to that of a synchronous brake, as if the synchronous machine in the two-motor set used for illustration could not develop sufficient mechanical power and therefore could act only as a generator. The pull-out torque is approximately equal to the repulsion torque at synchronous speed. At light loads, the repulsion torque will overpower the synchronous braking torque, so to speak, and the machine will pull out of step and run above synchronous speed; if the slip-rings are merely short-circuited, the range of torques at which the motor will operate synchronously is rather limited and moreover the motor is unstable, tending to hunt, both of which facts make it unsuitable for photophone service. With d-c. excitation, the motor synchronizes more readily, is more stable over a larger range of loads and does not tend to hunt. Moreover with d-c. excitation, the pull-out torque will be approximately equal to the breakdown torque as a synchronous motor plus the repulsion torque at synchronous speed.

The d-c. excitation has another important effect; that of reducing the line current. The reasons for this are two-fold: First, the magnetizing component of the stator current is decreased, since the direct current sets up all or a portion of the revolving field which would normally be set up by the stator windings; that is, the repulsion motor, in effect, becomes armature-excited. Another effect, which becomes more important at light loads, is the reduction of the repulsion armature current. Perhaps an easy way to grasp the fundamental reason for this is to consider that at light loads, where the torque required by the load is less than the repulsion torque at synchronous speed, either the working flux or armature current must be less than it would be for repulsion operation at synchronous speed; the flux is essentially constant and therefore the repulsion armature current, and to some extent the stator current on account of reduced losses, is smaller than it would be if the motor were operating as a straight repulsion motor at synchronous speed.

The performance of this unusual motor can be figured from the theory of the synchronous motor and the theory of the repulsion motor. However, the many irregularities will make it difficult to obtain accurate results.

Test Data

Various oscillograms were taken on one of the photophone motors built. Fig. 2 shows the direct-

current, line voltage, and stator current when the motor was run as a straight synchronous motor with the repulsion brushes lifted from the commutator. The oscillogram shows in a very pronounced manner the pulsation of the direct current and the distortion in the stator current. The applied a-c. voltage, of course, was not distorted.

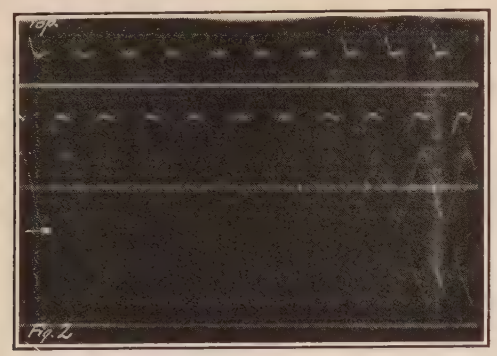

Fig. 2—As Synchronous Motor

12 amperes, d-c. excitation, repulsion brushes lifted, load = 12 oz-ft., 1.55 stator amperes. Top curve, stator a-c. amperes; middle, the line voltage; bottom = exciting current

In Fig. 3 are shown oscillograms of the direct voltage, direct current, and the alternating current through the short-circuited repulsion brushes when the motor was run as a synchronous-repulsion motor. Due to the short-circuited repulsion brushes, the pulsation of the direct current is slightly greater than shown in Fig. 2. The rotor current, or current through the brushes, shows some distortion.

In Fig. 4 are shown oscillograms of the line voltage, and of the stator and rotor currents, with the same load

Fig. 3—As Repulsion Synchronous Motor

12 oz-ft. load, 220 volts, 1.6 amperes a-c., 1800 rev. per min. Top-d-c. volts across brushes of sling-rings; middle, d-c. amperes; bottom, rotor a c. amperes.

conditions as in Fig. 3. It will be noted that the stator current is distorted much more than the alternating rotor current, and that this distortion is quite different from that in Fig. 2 where the machine is run as a synchronous motor. This difference, of course, is due to repulsion motor action. In addition to the distortion caused by the pulsation in the exciting current, the curves show smaller ripples which are probably caused by the teeth and commutator bars. In Fig. 5 are shown oscillograms taken with the motor operated as a plain repulsion motor delivering the same output torque at a higher speed.

Figs. 6 to 11 show a few test curves of the same motor which was a ¼-hp., 60-cycle, 220-volt, 4-pole, single-phase machine. In Fig. 6 is shown the no-load saturation curve, the motor being externally driven at 1800 rev. per min. In Fig. 7 are plotted the input amperes

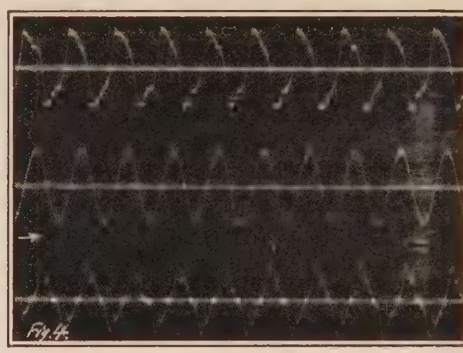

Fig. 4—As Repulsion Synchronous Motor

12 oz-ft. load, 1800 rev. per min. Top curve, stator a-c. amperes; middle 220-volt line volts; bottom, rotor a-c. amperes

and watts at different exciting currents when the machine was operated at no-load as a straight synchronous motor. At 15 amperes excitation, the alternating current has assumed its lowest value, and this checks with Fig. 6 where at 15 amperes the generated voltage is 220; *i. e.*, equal to the line voltage.

Fig. 8 shows the results of a brake test as a synchronous motor with 12 amperes d-c. excitation, the repulsion brushes being lifted from the commutator. Fig. 9 shows the result of a brake test as a straight

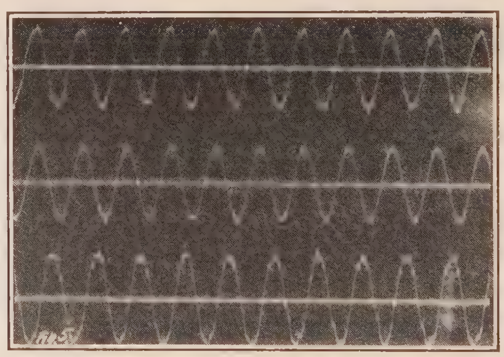

Fig. 5—As Repulsion Motor

12 oz-ft. load, 220 volts, 2230 rev. per min., 2.74 stator amperes and 112.2 rotor amperes. Top, stator amperes; middle, line volts; bottom, rotor amperes

repulsion motor and Fig. 10 the result of a brake test as a synchronous-repulsion motor with 12 amperes excitation. Finally, Fig. 11 shows the results of a brake test as a synchronous-repulsion motor without d-c. excitation, the leads of the collector rings being short-circuited.

In these curves, the efficiency and watt input do not include the watts supplied from the d-c. source for excitation. The measured pull-out torque as a synchronous motor was found to be 20 oz.-ft. and the repulsion motor torque at 1800 rev. per min. was 26 oz. ft. These two torques added together give 46 oz-ft., and it was noted from test that the pull-out torque as a synchronous-repulsion motor was 50 oz-ft. This small difference may have been due partly to errors in test, for it is difficult to obtain accurate pull-out torque readings on a motor with a brake-arm.

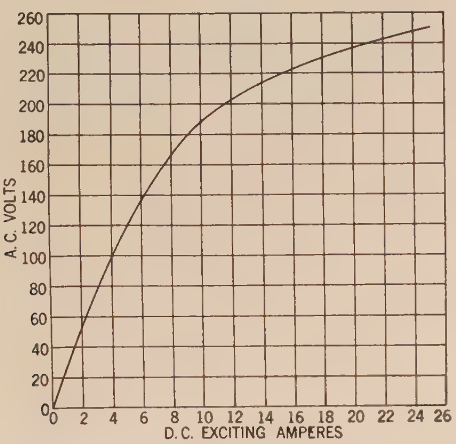

FIG. 6—SATURATION CURVE AT 1800 REV. PER MIN.

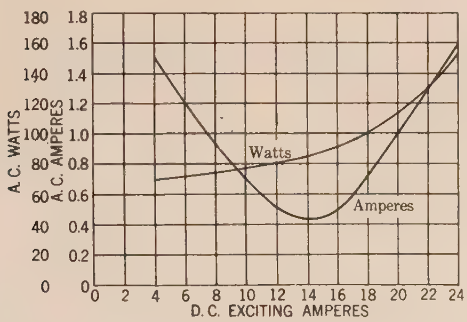

FIG. 7—SATURATION AS A SYNCHRONOUS MOTOR WITH BRUSHES UP

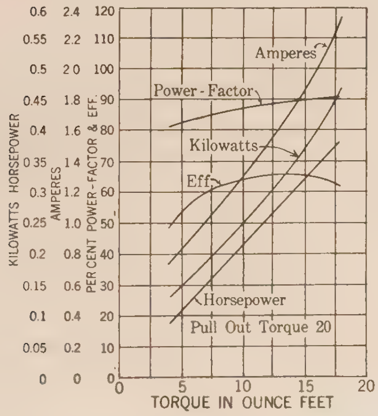

FIG. 8—BRAKE TEST AS SYNCHRONOUS MOTOR AT 1800 REV. PER MIN., 12 AMPERES DIRECT CURRENT

Further, it will be noted that under a heavy load, the performance as a synchronous-repulsion motor is the best; under a light load the efficiency as a synchronous motor is better because there are no brush friction losses nor losses in coils short-circuited by brushes as the latter are raised from the commutator. A brake test as a synchronous motor was also taken with the repulsion brushes down on the commutator and in this test,

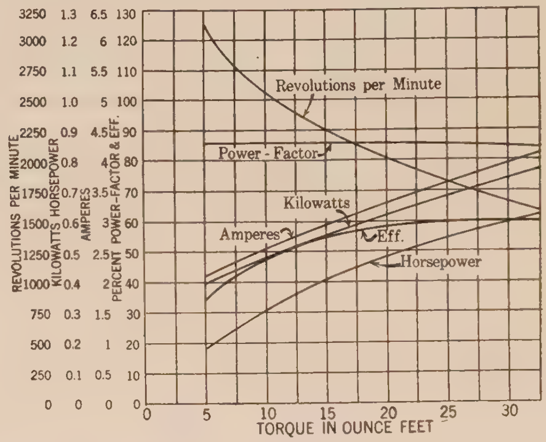

FIG. 9—BRAKE TEST AS REPULSION MOTOR

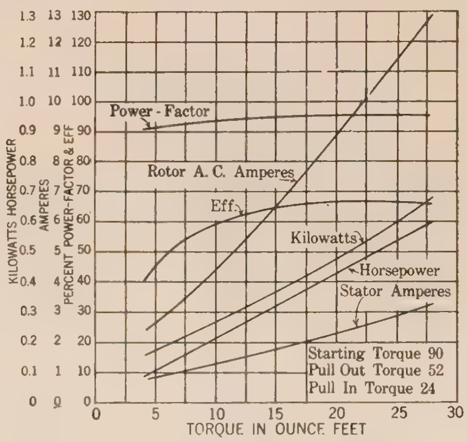

FIG. 10—BRAKE TEST AS SYNCHRONOUS REPULSION MOTOR AT 1800-REV. PER MIN., 12 AMPERES DIRECT CURRENT

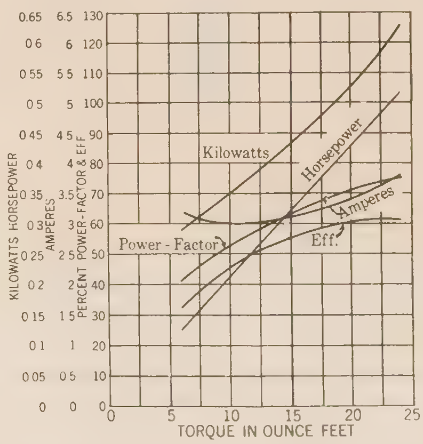

FIG. 11—BRAKE TEST AT 1800-REV. PER MIN., AS SYNCHRONOUS-REPULSION MOTOR WITHOUT D-C. EXCITATION

the watt input at lighter loads were as high as on the synchronous-repulsion motor test.

The pull-in torque as a synchronous-repulsion motor was observed to be 24 oz-ft. With d-c. excitation, the speed was very steady when in synchronous operation from no-load up to about pull-out, whereas, when the

d-c. leads were short-circuited, the motor fell out of step at either 6 oz.-ft. or 25 oz.-ft.; *i. e.*, if the load torque were less than 6 oz.-ft., the motor would pull out and run above synchronous speed, and at loads in excess of 25 oz-ft., the motor would pull out and run below synchronous speed. This demonstration shows quite clearly that without d-c. excitation, the machine cannot carry such a high overload torque as a synchronous motor as it can with d-c. excitation. Moreover, without d-c. excitation, hunting was quite noticeable. These conditions could have been improved somewhat by inserting some resistance between the repulsion brushes. Furthermore, it was observed that the commutator bars to which the slip-rings were connected, had a tendency to burn.

Conclusion

This photophone motor is very simple in operation, synchronizes readily at all loads, and can carry considerable overload. Furthermore, it is quite efficient and has a particularly good power factor. It is therefore quite satisfactory for photophone drives.

The author wishes to acknowledge gratefully the valuable assistance rendered him by Messrs. H. E. Newhouse and C. G. Veinott in performing the tests described and in preparing this paper.

Abridgment of

Thyrite

A New Material for Lightning Arresters

BY K. B. Mc EACHRON[1]

Member, A. I. E. E.

Synopsis.—*A new material has been developed which is peculiarly adapted for use in lightning arresters. Physically, it is similar to dry process porcelain, and it can be made in any shape that can be successfully moulded. The manufacturing processes have been perfected so that the electrical and mechanical characteristics can be duplicated or varied as desired within practical limits.*

This material, which is called thyrite, does not follow Ohm's law, for each time the voltage is doubled, the current increases 12.6 times. The ratio of change of current to change in voltage is constant over ranges of current of 10,000,000 to one. This means that the resistance decreases as the current and voltage increase. The resistance at any particular value of voltage or current is fixed by the physical dimensions of the piece. It is slightly lowered at high temperatures but returns to normal when cooled. The resistance does not depend upon the rapidity of current or voltage change and it is unaffected by long service. Because of the definite characteristics of thyrite, the action of lightning arresters can, for the first time, be accurately calculated.

Thyrite is now being used experimentally in three types of lightning arresters. The station type is made in 11.5-kv. sections, each containing its own gap unit so that no series arrester gap is required. These gap units have the desirable property of sparking over at practically the same voltage, irrespective of wave front. The 11.5-kv. sections are assembled in the field in the same manner as pedestal insulators.

The distribution arresters are smaller than those of the station type and have but one-fourth of the impulse current carrying capacity. For discharge currents up to 1000 amperes, neither of the arresters will allow more than 2.8 times the arrester rating in crest volts to appear across it.

The third type of arrester is incorporated directly in the transmission line suspension insulators, and is designed to absorb a considerable portion of abnormal surge energy as well as to protect the insulators from flashover.

This new line of lightning arresters has the following advantages:

1. *Ample protection for all insulation.*
2. *Conservative factor of safety from failure.*
3. *Permanence.*
4. *Small size and weight.*
5. *Low installation cost.*
6. *Invariable characteristics and predictability of results for any given condition.*
7. *Characteristics which can be measured by the user.*

* * * * *

The Ideal Arrester

A lightning arrester must be able to protect apparatus from the harmful effects of lightning and must prevent or suppress the flow of system follow current after the discharge has passed through the arrester.

The ideal arrester may be defined as one which passes zero current as the applied potential is increased until the critical discharge voltage is reached, when current begins to flow in whatever amount is needed to hold the potential across the arrester constant at the initial discharge value. The critical voltage for such an arrester should be unaffected by the rate of voltage application.

If the potential remains constant for any current, then the resistance varies from infinite resistance at zero current to zero resistance at infinite current. Thus the $R\,I$ curve is an equilateral hyperbola and its equation is $R\,I = C$ where C is numerically equal to the critical voltage.

If log R is plotted against log I, then the curve is a straight line having a slope of 45 deg. This slope is important, for in the general equation, which is $R\,I_a = C$, the exponent a is the slope of the $R\,I$ curve when plotted on log-log paper. Thus, for the ideal case, the slope is one (tan 45 deg. = 1), and the equation is $R\,I^1 = C$. When I = one ampere, then $R = C$ no matter what the exponent may be. Thus when a and C are known, the characteristic is immediately known, for C determines the position of the curve and a determines its slope.

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

Lightning Arrester Material—Thyrite

In the search for a suitable arrester material, the first requisite is that it shall have a high exponent, although it may not be possible to reach the ideal of one. If possible, the characteristic should not be affected by the rate of voltage application or the rate of current rise through the material. Its characteristic should not be affected by either the increase or decrease of current.

A search for a material having the properties described was begun in 1923, and this paper is the first public announcement of the results of that work. A material having mechanical properties somewhat similar to those of dry process porcelain, but possessing the remarkable property of being substantially an insulator at one potential and a good conductor at certain higher potentials, has been developed. This material called thyrite[2] represents a new class of conductor which covers the middle ground between the insulator and the conductor.

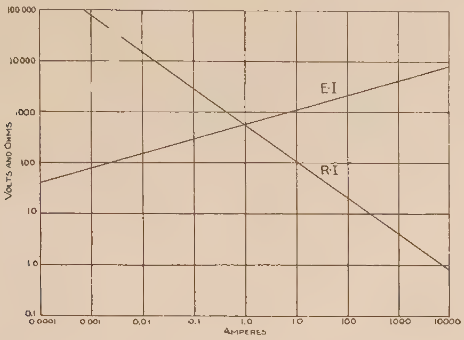

Fig. 1—Characteristic *E-I* and *R-I* Curves

For a thyrite disk 6 in. in diameter and ¾ in. thick

At the present time, thyrite for arrester use is manufactured in the form of disks, six inches in diameter by three-quarters of an inch thick; also three inches in diameter by one inch thick.

In Fig. 1 are plotted the $E\,I$ and $R\,I$ characteristics for a six-inch thyrite disk, for which $a = 72$ and $C = 580$ respectively.

Time Lag. The tests made have not disclosed any time lag in this material. This seems reasonable, for the material always acts as a resistance, and its operation does not depend on any arcs or sparks or the breakdown of any dielectric.

Operation on Alternating Current. Since the current varies as the $\frac{1}{1-a}$ power of the voltage, with an exponent 0.72 the current will vary as the 3.57 power of the voltage. With a sine wave of applied potential, the current wave will not be a sine wave. Therefore, it is desirable always to speak of both the voltage and current in terms of actual instantaneous values and not effective values. If energy loss in the piece with an applied sine wave voltage is desired, the product of the crest voltage and the crest current is to be multiplied by a factor.

Effect of Change in Temperature. The effect of increase in temperature is to lower the resistance of the material, especially at the weaker current values. When cold, the original values reappear. For the usual temperature changes in an arrester under operating conditions, the effect on the resistance will be small.

Permanence and Life. Several samples of the first thyrite made have been on life test for more than five years, and the tests have shown the characteristics to be practically unchanged. Other tests have been made in which the sample was exposed to the weather for a year, and no deterioration has been detected. Still other samples have been tested with both impulse and alternating current applied, and no changes in the material were noted, even after several hundred impulses.

The Arrester

In designing lightning arresters for all voltage ratings, it is worth while to build them in the form of standard units. This will greatly simplify manufacturing and stocking the arresters. For certain conditions it may be necessary to supply smaller or part units. The standard unit is rated 11.5 kv., grounded neutral. The arrester does not employ a series gap, each unit being complete within itself and containing its own gap structure. Fig. 2 shows six units in series, such as would be used on 69-kv. grounded neutral.

Fig. 2—69-Kv. Thyrite Lightning Arrester

Performance Characteristics. For the first time in the history of lightning protection it becomes possible to calculate arrester performance accurately. The volt-ampere curve for the 11.5-kv. unit is given in Fig. 3 and is the curve for 11 six-inch disks in series, making a total height of 8¼ inches. It is necessary to use a series gap arrangement, which is housed in each 11.5-kv. container.

The reason for the series gap will be apparent from an examination of the characteristic curve. The normal voltage to ground is 9.4-kv. crest, which would cause a steady current of four amperes crest to flow through the arrester continuously. If an overvoltage is applied, as

2. Thyrite—meaning gate, or opening.

may occur in the case of dropping a load and overspeeding generators, a potential as high as 16.2 kv. may be applied between line and ground. With this potential, a current of 28 amperes would flow, and thus for safe operation it is necessary that the gap be capable of stopping the flow of current after one-half cycle, even if the impressed potential is 16.2 kv. and the current 28 amperes. A single arrester gap is unable to break an arc of this magnitude. Because of the necessity of introducing several small gaps in series, two opposing conditions develop. With a 60-cycle voltage applied, the distribution of potential between the gaps must be kept uniform. At the same time, unless some means

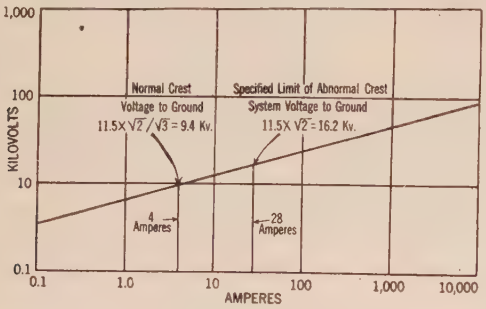

FIG. 3—CHARACTERISTIC OF 11.5-KV. GROUNDED NEUTRAL THYRITE LIGHTNING ARRESTER

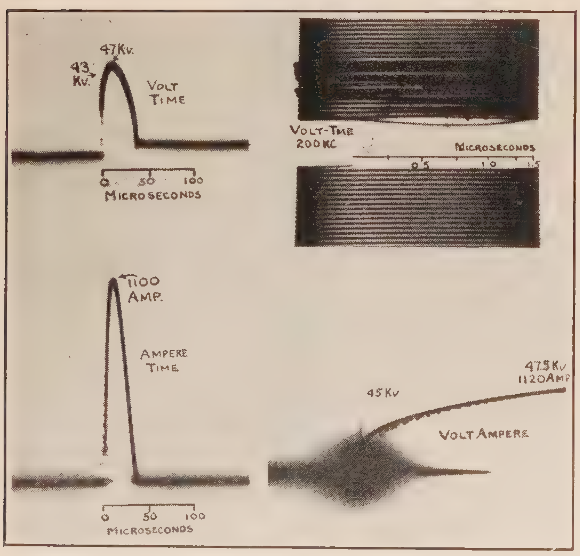

FIG. 4—PROTECTIVE CHARACTERISTICS OF 11.5-KV. THYRITE LIGHTNING ARRESTER

could be found to upset the uniform distribution under impulse conditions, the arrester breakdown would be too high for satisfactory protection. Fortunately this problem has been solved so that with the application of system potential, a uniform distribution is obtained, but the distribution becomes non-uniform when a steep wave front of potential is applied. Thus the impulse ratio is kept close to one; as, for example, the breakdown of the series gap at system frequency is about 35-kv. crest, while with the application of an impulse requiring one microsecond to reach breakdown it is about 45-kv. crest. Thus for currents up to 1000 amperes, the arrester unit holds the voltage to a value not in excess of 2.8 times its rating.

Cathode ray oscillograms taken on a complete 11.5-kv. unit are given in Fig. 4.

It should be noted that in this illustration the volt-ampere curve shows no loop, the increasing and decreasing characteristics following the same curve. The close agreement between this volt-ampere curve and the curve of Fig. 3 illustrates how accurately the arrester characteristics can be determined.

When applying arresters, it is very desirable to be able to determine the performance characteristics. In Fig. 5 are shown the characteristic curves for arresters whose ratings extend from 46 to 230 kv., grounded neutral.

Plotted on the same sheet are curves which the author calls impulse regulation curves for the transmission line. The arrester is considered for the given case to be at the end of a transmission line whose surge impedance is 500 ohms. For each arrester rating, an impulse regulation curve is taken, corresponding to the flashover value of the insulation used on that line. If, for 230 kv., 14 insulator disks were used, and for 138 kv., 10 disks were used, the corresponding flashover voltages are 1900 kv.

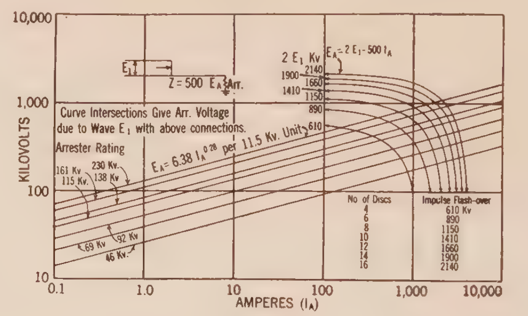

FIG. 5—GROUNDED NEUTRAL THYRITE ARRESTER CHARACTERISTICS WITH TRAVELING WAVES

and 1410 kv. The curved lines represent the potential across a resistor at the end of the line, which allows the corresponding current to flow. The value of voltage where the arrester volt-ampere curve crosses the impulse regulation curve for the corresponding number of insulators used represents the maximum voltage allowed by the arrester.

By similar methods, the arrester potential can be calculated for almost any assumed circuit condition so that arrester protection performance can be predicted accurately.

The condition of direct stroke, if occurring within one span length of the arrester but with an insulator string in between, has been assumed to be equivalent to that of a traveling wave having a potential equal to the insulator flashover, such as might result from an induced potential of twice the insulator flashover. On the assumed 230-kv. circuit, this potential is nearly 4,000,000 volts, which is much in excess of any potential yet indicated by the surge investigations on such a line. Curves similar to those of Fig. 5 show that under such an extreme condition, the arrester potential would be 1300 kv., which is still safe for the modern transformer. It seems certain that such potentials could occur only in connection with direct strokes very close to the point of connection of the arrester to the transmission line, and

could not represent a possible induced condition with present insulation levels.

The Arrester Unit. The arrester unit for 11.5-kv. grounded-neutral service as designed at present is 14½ in. high and 12 in. in diameter. It weighs about 100 lb. The unit is sealed, as no venting is necessary with this new arrester. If it is desired to check the arrester's characteristic, this can be done by the use of the ordinary oscillograph. If arrangements are made to measure voltage and current by the use of the oscillo-

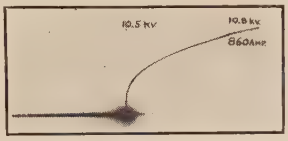

Fig. 6—Volt-Ampere Characteristic of 3000-Volt Thyrite Lightning Arrester

Gap sparks in one microsecond

graph, a few cycles of 60-cycle current can be made to pass through the arrester, and from the oscillogram showing voltage and current, the arrester characteristic can be determined accurately. Such a test cannot be prolonged, as the arrester would become hot and the series gaps would be burned.

Distribution Arrester. In the distribution arrester, thyrite disks one inch thick and three inches in diameter are used. The 3-kv. arrester requires two disks in series. It has a volt-ampere characteristic of design similar to the station type arrester for the same rating. Thus at 1000 amperes, the arrester potential is 2.8 times the arrester rating. Since the distribution arrester is provided with but one-fourth of the area of the station type, it has but one-fourth of the current carrying capacity. A cathode ray oscillogram giving the volt ampere characteristic for the 3-kv. arrester is shown in Fig. 6.

Transmission Line Type Arrester. Probably the least reliable part of electric transmission is the transmission line itself during lightning storms. No transmission line which is proof against lightning flashovers has yet been built. The number of flashovers has been reduced by the use of ground wires and extra insulation, but they have not yet been eliminated. From the standpoint of interruption to service, two methods of attack are available; one, to render the flashover innocuous by the use of such devices as the fused grading ring or the Peterson coil, and the other, to prevent the flashover by whatever means is possible.

The better method is to prevent the flashover and, if possible, at the same time absorb a considerable portion of the energy of the charged capacity of the line by the use of some device, such as a lightning arrester.

The idea of using arresters along a line is not new, but suitable arresters have not been available from the standpoints of either size or cost.

The new arrester material will, it is believed, offer a means of protecting insulator strings on towers at a cost which is reasonable, and it should greatly increase the reliability of transmission lines.

An arrester for the protection of transmission line insulators is shown in Fig. 7. It is rated 69 kv. and uses 72 disks three inches in diameter and one inch thick; so that the protective characteristic would correspond to a station type rated 108 kv. According to to Fig. 5, with a current of 2000 amperes flowing, the arrester potential is about 500 kv., while the flashover for four insulators is 610 kv., or for six insulators is 890 kv.

It is probable that experience will show that the number of disks can be reduced, improving the protection afforded and also reducing the cost of the arrester. With such application of arresters, it is not necessary that the arrester have large discharge capacity, as several would operate in parallel. Whether or not such protection would eliminate flashovers due to direct strokes is not known. It is the intention to try out arresters of this character on at least two transmission lines this summer.

Failure Tests

Many careful tests have been conducted on low-voltage units of all three types in the factory in which were supplied both 60-cycle power and impulses timed to strike at the most dangerous point on the wave.

In May 1929, a 66-kv. thyrite arrester was tested on a 66-kv. transmission line with the line energized at normal potential, the impulse being supplied with a million-volt portable generator. During the test, the six units were reduced to four which withstood many impulses

Fig. 7—69-Kv. Transmission Line Lightning Arrester

with no signs of distress. So far as the author is aware, this is the first time that a high-voltage arrester has been tested in this manner.

Acknowledgments

The author wishes to express his appreciation to Messrs. J. R. T. Craine, L. H. Whitney, and A. C. Campbell for their assistance in the development of thyrite. Their help has been invaluable. Messrs. E. M. Duvoisin, E. G. Newton, and L. W. Evans have all had a large share in the development of the arrester, while to Mr. T. Brownlee, the author is indebted for assistance in the preparation of the paper.

Calculation of Protection of a Transmission Line by Ground Conductors

BY HERBERT BRISTOL DWIGHT[1]

Fellow, A. I. E. E.

Synopsis.—*This paper discusses the well-known calculation of the degree of protection afforded to a transmission line by ground conductors, on the assumption of the sudden disappearance of a vertical potential gradient caused by a charged cloud. Formulas are given for the protective ratio due to one and two ground conductors. It is shown that for any number of ground conductors, it is not necessary to compute the charges on the power conductors.*

* * * * *

In calculating the degree of protection afforded to a transmission line by its ground conductors, a calculation which is frequently used by electrical engineers is that based on the assumed sudden disappearance of a large potential gradient from the earth upward. Such a calculation was described by R. P. Jackson[2] in 1907, and by E. E. F. Creighton[3] in 1916.

In this paper are given some formulas for particular cases, and some methods for shortening the work of calculation.

The calculation of protective factor is based on the assumption that a vertical potential gradient is induced by a charged cloud, and that this causes charges to collect on all the conductors; then the gradient is suddenly removed when the cloud discharges. The charges on the ground conductors go to earth very quickly to a sufficient degree to bring the potential of the ground conductors to zero. The charges on the insulated conductors remain long enough to raise the potential of those conductors, and if the potential is high enough, to cause a flashover of an insulator. The protective factor is the ratio of the potential of the power conductor when protected by ground conductors, to its potential if it were not so protected.

In the calculation described by Mr. Creighton, the values of the charges on all the conductors in the system were found. It will be shown that by finding charges on the ground conductors when the power conductors are considered absent it is possible to calculate the protective factor according to the standard theory. This reduces the number of simultaneous equations to be solved and shortens the work considerably.

Let there be ground conductors $G_1\, G_2 \ldots\ldots$ and insulated power conductors $A.\ B.\ C \ldots\ldots$ all parallell to each other.

If there is a voltage gradient, each conductor takes up a charge so that when a unit charge is carried from the image of a given conductor to that conductor, the work done by all the charges is equal to the voltage gradient multiplied by twice the height of the given conductor. The power voltage is neglected. If the gradient is suddenly removed and none of the charges is changed, the voltage on each conductor is equal to the gradient times its height.

Now the ground conductors are presumed to have their charges reduced or changed very quickly, so that each ground conductor has zero potential, before any appreciable change takes place in the charges on the insulated power conductors.

The reduction in the work done by the charges in carrying a unit charge from the image of a given ground conductor to that conductor is dependent upon the reduction in charge of the ground conductors. It is not dependent upon the presence or size of the charges on the power conductors, since, according to the assumption made, those charges do not change. The reduction in the charge on each ground conductor is therefore not dependent upon the size or position of the power conductors, and may be calculated by assuming the power conductors to be absent.

Fig. 1—Ground Conductors and Power Conductors and Their Images

The reduction in voltage on a given power conductor such as A is equal to one-half the reduction in the work done on a unit charge carried from the image of A to A. This is dependent upon the reduction in the charges on the ground conductors, and this has been shown to be unaffected by the presence of the power conductors. Since the charge on A does not change, the reduction in voltage on A does not depend upon the shape or diameter of A, but merely on the position of A. The protective ratio of A is obtained directly from the reduction of voltage on A, described above.

It is possible, therefore, to calculate the protective

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1. Massachusetts Institute of Technology, Cambridge, Mass., and New England Power Construction Company.

2. R. P. Jackson, A. I. E. E. Trans., 1907, p. 873.

3. *Theory of Parallel Grounded Wires*, by E. E. F. Creighton, A. I. E. E. Trans., 1916, p. 845.

Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Printed complete herein.

ratio for one power conductor near a group of ground conductors by assuming that the other power conductors do not exist. It is also possible to plot curves showing the protective ratio around a group of ground conductors, and these curves will be the same for power conductors of any diameter. (See Figs. 2, 3, 4, and 5.)

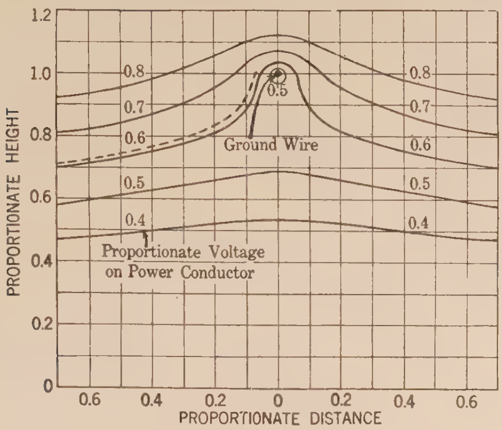

FIG. 2—SINGLE GROUND WIRE

Full lines, ground wire ½ in. diameter; 80 ft. average height
Dotted line, ground wire ⅜ in. diameter; 35 ft. average height

In overhead work, when measuring the distances to the other conductors. the diameter of a conductor is negligible compared with the distance to other conductors. Similar sets of curves obtained by this same general method were given by R. P. Jackson. (Ref. 2.)

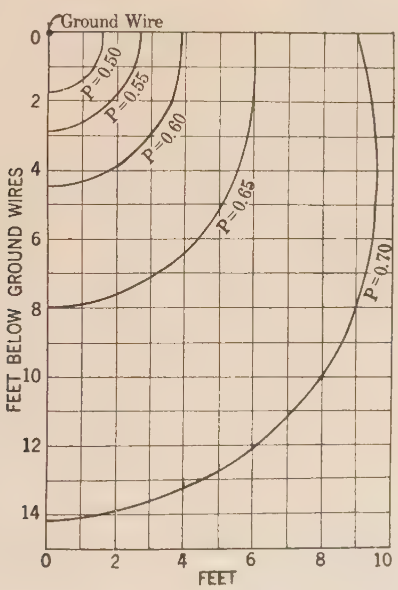

FIG. 3—PROTECTIVE FACTOR, P, DUE TO ONE 7/16-INCH GROUND WIRE; 65 FT. AVERAGE HEIGHT.

Typical of a steel pole line

The above paragraphs show that in computing the protective ratio for the power conductor A, it is not necessary to find the value of the charge on A. This makes the number of simultaneous equations to be solved equal to the number of ground conductors. In most cases, the arrangement of the ground conductors is symmetrical when all the power conductors are considered absent, and some pairs of charges can be put equal to each other. The number of simultaneous equations to be solved is then equal to approximately one-half the number of ground conductors. The one main calculation will give the protective ratio for all the power conductors. Thus, the calculation becomes as follows:

Find the charges on the ground conductors due to the

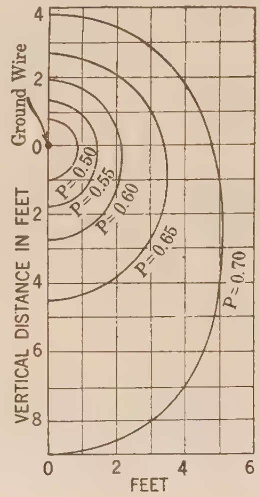

FIG. 4—PROTECTIVE FACTOR, P, DUE TO ONE ⅜-IN. GROUND WIRE, 28 FT. AVERAGE HEIGHT.

Typical of a wood pole line

voltage gradient, all the power conductors being considered absent. Then carry a unit charge from the image of any of the power conductors to that conductor. This gives the reduction in voltage on that conductor due to suddenly grounding the ground conductors,

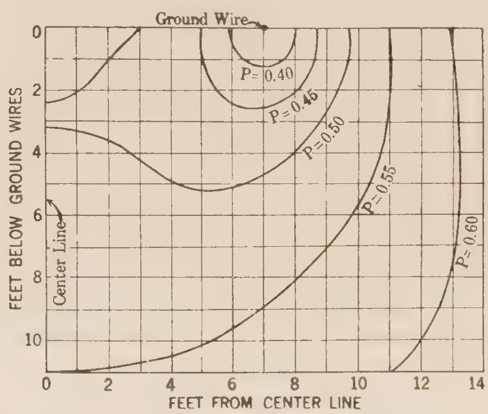

FIG. 5—PROTECTIVE FACTOR, P, DUE TO TWO 7/16-IN. GROUND WIRES, 14-FT. SPACING AND 40 FT. AVERAGE HEIGHT.

Typical of H-frame transmission lines

assuming them to be first insulated and holding the charges left by the gradient. By subtracting this reduction from the original voltage at the power conductor A caused by the gradient, one finds the final voltage on A, and hence the protective ratio for A.

This shorter method of calculation has been checked for some practical numerical examples by solving them by both the shorter and the longer methods, the same result being obtained by both methods.

It has been found by Mr. H. H. Spencer of the New

England Power Construction Company, that considerable time and effort in performing the calculation and checking it are saved in most cases by expressing the result of the simultaneous equations by determinants which are symmetrical about a diagonal, and then employing the Doolittle Method of evaluating the determinants.

The mirror symmetry which this method of solution of ground wire problems involves leads to a simplification in the evaluation of the charges on the ground conductors through the solution of the simultaneous equations.

Regardless of the arrangement of the ground conductors, the simultaneous equations for their charges can be so arranged that the determinant of the equations will be symmetrical about the principal diagonal; that is, the equations can always be so arranged that they will be of the form:

$$\begin{aligned}
a_1 Q_1 + b_1 Q_2 + c_1 Q_3 + d_1 Q_4 + \ldots + r_1 Q_n - K_1 &= 0\\
b_1 Q_1 + b_2 Q_2 + c_2 Q_3 + d_2 Q_4 + \ldots + r_2 Q_n - K_2 &= 0\\
c_1 Q_1 + c_2 Q_2 + c_3 Q_3 + d_3 Q_4 + \ldots + r_3 Q_n - K_3 &= 0\\
d_1 Q_1 + d_2 Q_2 + d_3 Q_3 + d_4 Q_4 + \ldots + r_4 Q_n - K_4 &= 0\\
\cdots\quad\cdots\quad\cdots\quad\cdots\quad\cdots\quad\cdots &\\
r_1 Q_1 + r_2 Q_2 + r_3 Q_3 + R_4 Q_4 + \ldots + r_n Q_n - K_n &= 0
\end{aligned}$$

Equations of this form are much used in statistical work and a form of solution for them, well known by statistical men but not much employed by engineers, is the Doolittle Method.[4] This method consists of so tabulating and arranging the work that it becomes self-checking and at each step of the operation, columns are footed and lines extended so that the sums obtained give a numerical check on all the work done up to that point. This removes to a large measure the tediousness of solving large numbers of simultaneous equations, since the computer is relieved of the dread that an error may have been made, necessitating the repetition of a large volume of labor. In a ground wire problem involving a large number of ground conductors, 13 simultaneous equations were solved by this method in rather less than one-half the time required for solution and checking by the usual determinantal methods.

For one or two ground conductors, formulas for the protective ratio are advantageous, but for more ground conductors it is probably better to use numerical coefficients and solve the simultaneous equations.

The protective ratio with one ground conductor is

$$1 - \frac{h_G}{h_A}\;\frac{b}{a} \tag{1}$$

where

$$a = \log_{10} \frac{G\,G'}{r_G}$$

$$b = \log_{10} \frac{A'\,G}{A\,G}$$

4. Frederick C. Mills' "Statistical Methods," Henry Holt and Company, 1924; pp. 577-581.

h_G = height of ground conductor above the earth,
h_A = height of power conductor A above the earth,
r_G = radius of ground conductor,
$G\,G'$ = distance of ground conductor to its image, and so on.

Equation (**1**) corresponds to Equation (**28a**) of Reference 3, which contains an error.

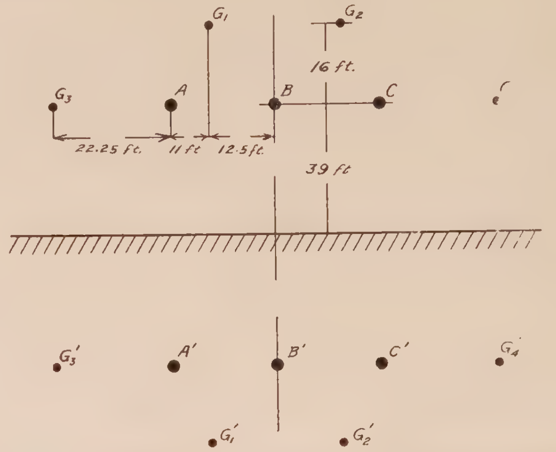

FIG. 6—TRANSMISSION LINE WITH FOUR GROUND CONDUCTORS

The protective ratio of power conductor A with two ground conductors G_1 and G_2 is

$$1 - \frac{(b\,e - c\,d)\,h_{G2} + (c\,e - b\,f)\,h_{G1}}{(e^2 - d\,f)\,h_A} \tag{2}$$

where

$$b = \log_{10}\frac{A'\,G_1}{A\,G_1} \qquad e = \log_{10}\frac{G_1'\,G_2}{G_1\,G_2}$$

$$c = \log_{10}\frac{A'\,G_2}{A\,G_2} \qquad f = \log_{10}\frac{G_2'\,G_2}{r_{G2}}$$

$$d = \log_{10}\frac{G'_1\,G_1}{r_{G1}}$$

If $h_{G1} = h_{G2}$ and $r_{G1} = r_{G2}$

$$\text{Protective ratio} = 1 - \frac{h_G}{h_A}\;\frac{(b+c)}{(d+e)} \tag{3}$$

Example—Four ground conductors (see Fig. 6).

$$r_{G1} = r_{G2} = 0.02083 \text{ ft.}$$

$$r_{G3} = r_{G4} = 0.015 \text{ ft.}$$

First assume that the power conductors are absent.

By symmetry, $Q_{G2} = Q_{G1}$ and $Q_{G4} = Q_{G3}$, these being charges per cm. of conductor.

Carry a unit charge from G_1' to G_1.

The work done against any charge such as Q_{G3} and its image is

$$4\,Q_{G3} \log n \frac{\text{old distance}}{\text{new distance}}$$

where "old distance" is the distance of the unit charge from the center of G_3 before the motion, and "new distance" is the distance from the center of G_3 after the motion takes place, and where log n denotes natural logarithm. Thus,

$$2\,g\,M \times 55 = 4\,Q_{G1}\log_{10}\frac{G_1'\,G_1}{r_{G1}} + 4\,Q_{G1}\log_{10}\frac{G_1'\,G_2}{G_1\,G_2} + 4\,Q_{G3}\log_{10}\frac{G_1'\,G_3}{G_1\,G_3} + 4\,Q_{G3}\log_{10}\frac{G_1'\,G_4}{G_1\,G_4}$$

where g = the gradient induced by the cloud, in statvolts per foot and $M = \log_{10} e = 0.4343$.

$$27.5\,g\,M = 4.377\,Q_{G1} + 0.694\,Q_{G3} \tag{4}$$

Carry a unit charge from G_3' to G_3

$$2\,g\,M \times 39 = 4\,Q_{G3}\log_{10}\frac{G_3'\,G_3}{r_{G3}} + 4\,Q_{G1}\log_{10}\frac{G_3'\,G_1}{G_3\,G_1} + 4\,Q_{G1}\log_{10}\frac{G_3'\,G_2}{G_3\,G_2} + 4\,Q_{G3}\log_{10}\frac{G_3'\,G_4}{G_3\,G_4}$$

$$19.5\,g\,M = 0.694\,Q_{G1} + 3.835\,Q_{G3} \tag{5}$$

Solving the simultaneous Equations (4) and (5)

$$Q_{G1} = 5.638\,g\,M$$

and

$$Q_{G3} = 4.064\,g\,M$$

To find the protective ratio of power conductor A, carry a unit charge from A' to A against the four charges on the ground conductors and their images which have just been derived, and let the voltage so found be $\overline{V}_{AA}'$.

$$\overline{V}_{AA}'\,M = 4\,Q_{G1}\log_{10}\frac{A'\,G_1}{A\,G_1} + 4\,Q_{G1}\log_{10}\frac{A'\,G_2}{A\,G_2} + 4\,Q_{G3}\log_{10}\frac{A'\,G_3}{A\,G_3} + 4\,Q_{G3}\log_{10}\frac{A'\,G_4}{A\,G_4}$$

$$\overline{V}_{AA}'\,M = 4 \times 9.18\,g\,M$$

$$\frac{1}{2}\,\overline{V}_{AA}' = 18.36\,g = \text{reduction in voltage on } A$$

$$\begin{array}{ll} 39\ \ \ g = & \text{voltage on } A \text{ left by gradient} \\ \hline 20.64\,g = & \text{final voltage on } A \end{array}$$

$$\text{Protective ratio of } A = \frac{20.64}{39} = 0.529$$

It is desired to make acknowledgment to Mr. L. O. Waite of the Stone and Webster Engineering Corporation for a number of contributions to this paper, among them Formulas (1) and (3) and Figs. 3, 4, and 5.

Abridgment of

Fundamental Plan of Power Supply in the Chicago District*

BY GEORGE M. ARMBRUST†
Member, A. I. E. E.
and
TITUS G. LeCLAIR†
Member, A. I. E. E.

Synopsis.—*This paper describes the design of a large metropolitan system, interconnected with a surrounding high-voltage transmission system. The region included in the scheme comprises an area of 6000 square miles, including the City of Chicago and is served by several companies with systems so interconnected as to form a consolidated scheme of generation and distribution. The physical limitations in locating generating stations within the metropolitan area at the load centers, and the economic advantage of locating stations for the greatest benefit to the group as a whole, makes this arrangement desirable. However, it imposes the necessity of transmitting large blocks of energy and a very free interchange of reserve capacity over the entire system.*

The system described as contrasted with the "loose linked" and "synchronized at the load" types is solidly interconnected, and because of the nature of its tie connections, it has inherently a very high degree of stability. The service standards of this system require the greatest possible reliability and continuity of supply. The general plan of the system, method of operation, and provisions for protection from the effects of excessive short-circuit currents, are described.

In the future development of this system, it is probable that within the next few years a considerable proportion of the total supply to the densely loaded portion within the City of Chicago, will come from stations located quite remote to the load. Energy will be transmitted into the city over a network of transmission lines at voltages from 66 to 220 kv. or higher.

Introduction

THE fundamental principles on which the general plan of a reliable and economical transmission and distribution system are based are largely determined by the distribution of population, load, and location of suitable sites for generating capacity.

The territory included in the Chicago region covers an area of 6000 sq. mi., centering about the City of Chicago, which has an area of 209 sq. mi. Surrounding the city is a suburban district of 1200 sq. mi., and beyond, small towns are spread over an area of 4800 sq. mi. The distribution of population is shown on the map of the region, Fig. 1.

This territory is supplied from the systems of the Commonwealth Edison Company, within the city of Chicago, the Public Service Company of Northern Illinois, and the Northern Indiana Public Service Company, immediately surrounding the city; and the further outlying regions, by the Middle West Utilities Company's subsidiaries. These systems are so interconnected and operated that the supply is equivalent to that from a single system.

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*Part I of Symposium on Power System Planning.

†Both of the Commonwealth Edison Company, Chicago, Ill.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

The estimated total load in the entire region for the winter of 1929-30 is 1,355,000 kw., of which 1,059,000 kw. is within the city of Chicago. The density of load is in general proportional to the distribution of population except for the greater load concentration at the center of Chicago. The maximum density in the downtown area in Chicago, which covers approximately a square mile, is 125,000 kw. per sq. mi. The average for the City of Chicago is about 5100 kw. per sq. mi., but for the total area in this region, it is only 230 kw. per sq. mi.

25-Cycle System

The original transmission system in the Chicago district consisted of 9000-volt 25-cycle lines, supplying synchronous converter substations in the central part

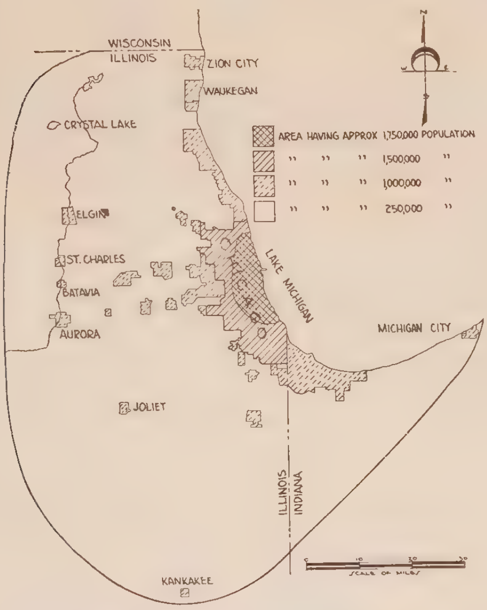

Fig. 1—Distribution of Population in the Chicago Region

of the city. Later, when the 60-cycle system was introduced, practically all of the increase in load was taken on this system and no 25-cycle generating capacity has been added since 1920. The 25-cycle system is supplied by 321,000-kw. generating capacity and two 40,000-kw. frequency changers.

The 25-cycle system as distinguished from the 60-cycle system has only two classes of load. One is d-c. light and power in the central part of Chicago, and the other class is electric railway service. All of this load is synchronous converters. At present, 95,000 kw., or about one half of the d-c. light and power system load and 226,000 kw. of the traction load is supplied from the 25-cycle system. These two classes have a coincident demand of about 313,000 kw.

The 25-cycle generating system is operated in three sections supplying substations arranged in small groups. The substations supplying the d-c. network are each fed from two sections, and these sections are alternated and interspersed with those supplied from the 60-cycle system in a manner that will come as near as possible to giving any point on the network a supply from several sections. The network is provided also with storage battery reserve.

After two very severe short circuits, these sections of the 25-cycle system were connected through reactors and all outgoing lines equipped with reactors, generators are also equipped with reactors and neutral resistors are used at each station.

The protection from short circuits on lines of the 9000-volt system is by the conventional time sequence in most cases. This time sequence is extended back to the generating station and includes relays in the supply to the line busses. Short lines are frequently protected by pilot-wire differential relays backed up by induction overload relays. Generators are equipped with ordinary instantaneous differential relays but not with overload relays. In case of a severe or prolonged overload, the operator is depended upon to open the switch if necessary before the generator actually fails.

With the present arrangement of the 25-cycle system, any cable fault at 9000-volts, either phase-to-ground or phase-to-phase, does not cause a serious interruption of service. When the fault is single-phase-to-ground, the effect is usually very small. Frequently in the case of phase-to-ground or a three-phase fault, there is some dropping off of synchronous converters and resultant transfer of load to other units. Since the installation of line reactors, there appears to be no serious danger of a complete shut-down of the 25-cycle load due to any possible fault on the system.

60-Cycle System

The 60-cycle system covers the entire Chicago region and supplies more than three-quarters of the total load. The estimated total 60-cycle load during the winter of 1929-30, for the entire region, is 1,073,000 kw., of which 745,000 kw. is in Chicago.

Within the city, energy is distributed by 12,000-volt lines arranged for a radial scheme of supply to small groups of substations. This supply is concentrated at several centers with no interconnection at the generating voltage but with a rigid connection between generating stations at a higher voltage.

The outlying territory surrounding Chicago is largely supplied by overhead 33-kv. lines interconnected in the form of a network.

Overlying the 33-kv. system is a 132-kv. trunk line which constitutes a fairly rigid connection between centers. The development of this system is reaching a point where the 33-kv. lines are not depended upon for interchange, with the result that the 33-kv. system will be rearranged into groups as shown on Fig. 13.

Practically all the secondary system is fed through substations supplying the d-c. network, 4000-volt feeders, railway systems, and large industrial customers on 12-kv. loops.

The 60-cycle distribution within Chicago is concentrated at five 12-kv. distribution centers, having a total generating capacity of 750,000 kw. and load of 745,000 kw. The corresponding generating capacity in the surrounding territory is 607,000 kw., with a load of 328,000 kw., making the total 60-cycle capacity in the entire region 1,357,000 kw., and the load 1,073,000 kw.

The 60-cycle 12-kv. substation supply is divided into two sections and this separation carried back to the generating stations. In the smaller stations up to 200,000-kw. capacity, these sections are normally tied together, but are cut apart during severe disturbances by the operation of overload relays on the generators. The generators, however, remain connected to the individual sections. The purpose of this scheme is to limit the spread of a very severe disturbance.

Sectionalization in the largest stations, such as Crawford Avenue, is accomplished by dividing the main busses by means of reactors into as many sections as may be necessary to limit the concentration of short-circuit energy. The two major systems are connected through a relatively high reactance at each end of the main busses. With this arrangement the station may be increased to an infinite capacity by increasing the number of divisions of the main busses.

For a station having a capacity intermediate between the largest and the smallest, the reactors may be installed between sections of each main bus without using the end reactors; or, on the other hand, the end reactors may be used without having the intermediate reactors between sections.

All of the 12-kv. lines emanating from the distribution centers are equipped with reactors which limit short-circuit currents to a value well within the rating of their circuit breakers. For protection against excessive values of current in the event of a short circuit in the switchhouse proper, phase isolation has been adopted for all switchhouses built in recent years and for a number of substations, particularly of the larger type. Short-circuit current is limited by three-ohm neutral resistors, one of which is connected to the generator neutrals in every station on each operating section.

The standard procedure for relay protection on 12-kv. lines is to use an inverse time induction overload relay at the source end of the line to the substation and a reverse power relay at the substation end, set to trip with power flow away from the substation. Short lines, however, are equipped with overload relays at the sending end and pilot wire relays at both ends. Generators are equipped with sensitive instantaneous differential relays. They are not, however, equipped with overload relays to trip the machine in case of severe overload. Protection from short circuits on the busses in the newer stations is provided by the newly developed fault bus system.

The 66,000-volt system within Chicago is somewhat unique in several respects. As contrasted with the systems synchronized at the load or by "loose linking," the system established by these 66-kv. lines constitutes, a rigid tie, or the equivalent of a sectionalized high-voltage bus extending from Northwest Station at the north to the State Line Station at the south. Because this system concentrates such a large amount of capacity, the first essential in its design is phase isolation throughout. Single-conductor cable is used so that faults in the lines themselves must all start from one phase to ground, and, in addition, transformers are single-phase with barriers between units. Fig. 9 shows the scheme of interconnection and sectionalizing on the 66-kv. system.

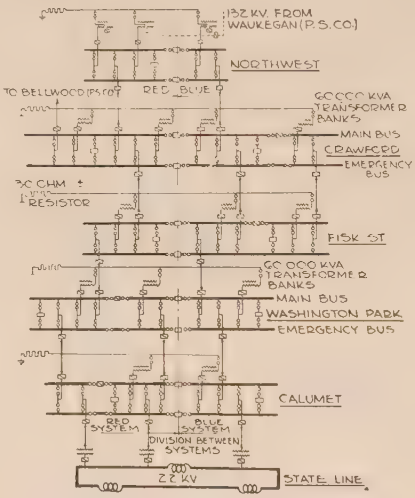

Fig. 9—General Diagram of 66,000-Volt System in Chicago

Sectionalizing at 66,000 volts is carried out to correspond with that at 12,000 volts; that is, the major division between the two systems also applies to the higher voltage.

The 66-kv. terminals are equipped for fault bus protection, and the lines are protected by a pilot wire scheme which gives practically instantaneous protection against either ground or between phase failure.

The transformers are equipped with differential relays, and because most of these transformers are three-winding with tap changing under load, the protection scheme is somewhat complicated.

Such a system as this, using transmission lines which are electrically very short and which form practically a high-voltage bus, contains very great inherent stability. The synchronizing power required to pull these lines out of step would be far beyond the limits of the ordinary fault currents. For this reason no special consideration need be given to the stability problem, as it would be on a system containing long overhead lines.

The interconnections of the Commonwealth Edison Company with the adjacent companies are made by means of 132-kv. overhead lines. Up to the present time the stability feature of 132-kv. lines has not been a serious operating problem, partly because the loads carried on the lines were considerably below the prob-

able stability limit and partly because the important lines were comparatively short.

The general arrangement of the 132-kv. system is shown in Fig. 11.

For the most economical operation of the system, accurate control of load division between separate stations of the network is of great importance. The Commonwealth Edison Company is using a system by means of which the load of each generating station is automatically indicated at the Load Dispatcher's Office and at the same time, an indication of the total load is sent back to each generating station. With this scheme, each station operator has before him the total system load as well as his own load. With the aid of

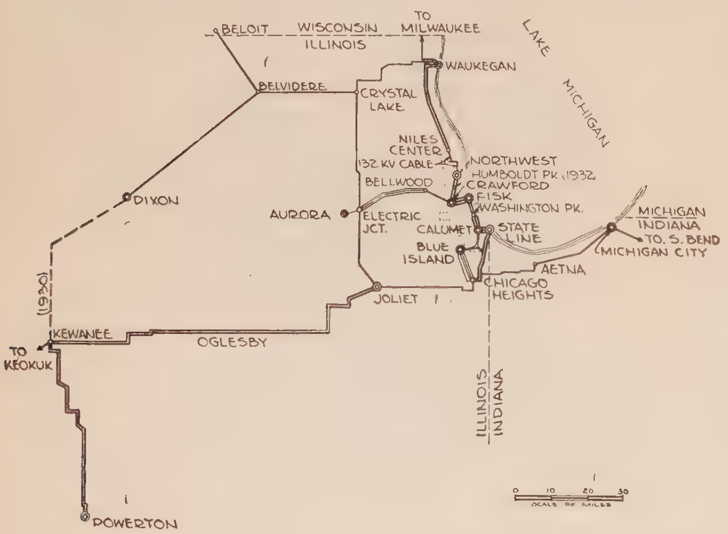

Fig. 11—Major Transmission System in the Chicago Area

Legend

--- Future lines

Lines—132 or 66 kv.

Lines—33 kv.

◎ Present generating station

⊗ Future generating station

○ Present substation

◌ Future substation

special charts showing the division of load between individual stations for any given total system load, the operator at each station knows his responsibility for the allotted portion of system load without telephone instructions.

With the advent of synchronous motor-driven clocks and more rigid interconnections in this region, the question of uniform and accurately measured frequency became of great importance. The Commonwealth Edison Company developed an automatic frequency control scheme by means of which it is not only possible to keep the instantaneous frequency of the system within about one-twentieth of a cycle, but also to correct any cumulative error which might result from a slight instantaneous error and therefore affect the time reading of the synchronous clocks. With this time correction feature, it is possible to hold the time on synchronous clocks normally within two or three seconds of the correct value.

Faults in the 12-kv. underground system, whether phase-to-ground or phase-to-phase, produce no appreciable effect on the remainder of the system except a slight flicker of the lights in the zone fed by the substation to which the faulty cable line is connected. Approximately the same effect is produced by failures on 33-kv. and 66-kv. underground lines.

A failure at the station itself, both on the 12-kv. and 66-kv. systems, is cleared by means of the fault bus. Since the installation of the fault bus there were several

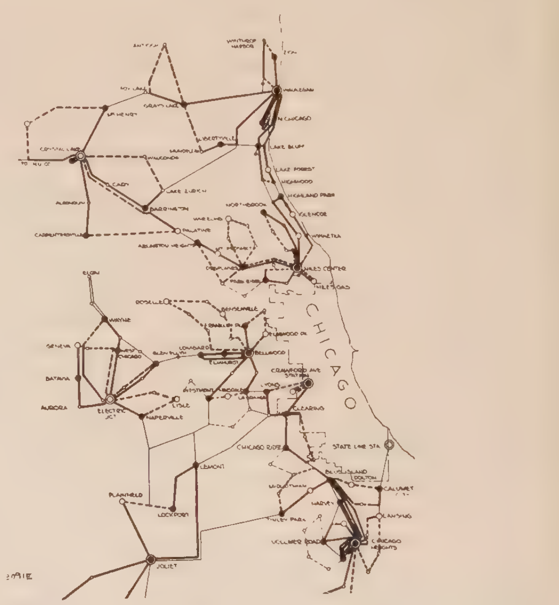

Fig. 13—33,000-Volt Transmission System in Region Around Chicago

operations under actual service conditions on the 12-kv. system and in each case the fault was cleared without disturbance.

The future development of this transmission scheme is based on load estimates for the entire region projected from five to ten years in the future and a survey of the possible and desirable sites for generating capacity to meet this demand. Within the city of Chicago it is planned to extend the 66,000-volt underground system which constitutes a duplicate bus extending through the city and interconnecting the generating stations. This will be of sufficient capacity to transmit the output of large efficient stations to load centers where it is not feasible to provide such generating capacity and will permit the free transfer of reserve capacity and most economical use of efficient units.

In order to improve efficiency of transmission and so far as possible to limit concentration of energy at distribution points, additional 66-kv. distribution stations will be provided.

Surrounding the city is an outer ring of 132-kv. overhead lines which will tie into the 66-kv. system at several points and extending outward to interconnect stations more remotely located.

As the future increase in generating capacity within the city is limited, an increasing proportion of the energy required will come from stations outside—some located at considerable distances. Transmission of large amounts of energy from the more remote sources into Chicago will be by means of overhead lines at 132 kv., 220 kv. or higher voltage and stepped down to 66 kv. at points as nearly as practicable to the load centers.

In the future, the basic conditions of the system will be changed as a larger portion of the energy comes from more distant sources instead of from sources near the load center. The reliability of service required for this metropolitan load must still be maintained. Stability of long lines and lightning protection, two influences which have not heretofore been a factor, will become major problems when these heavily loaded long circuits are relied upon as a continuous source.

With the development of generating stations of the order of 1,000,000 kw. outside the load center and with limited rights-of-way for tower lines, circuits must be designed for, and operated at, the maximum loading. To develop both overhead lines and underground cable for higher voltages and greater loads,—also, to apply the proper facilities for load and voltage control,—this will require much research and study.

Abridgment of

Development of the New Autovalve Arrester

BY J. SLEPIAN,* Fellow, A. I. E. E.
R. TANBERG,* Associate, A. I. E. E.
and
C. E. KRAUSE* Associate, A. I. E. E.

Synopsis.—*This paper describes the development of a new autovalve lightning arrester operating on the principle of discharge in restricted passages.*

A brief résumé is given of the improvements in performance and size desired in lightning arresters. Reference is made to laboratory tests on insulation protected with arresters to determine the limits of discharge voltage required for good local protection. Oscillograms show that the new autovalve arresters meet these requirements. Successful operating experience with these arresters is stated to give final verification of the results obtained in the laboratory investigations.

The steps in the development of materials are described and the materials finally chosen and the design of arresters are considered.

The performance is discussed and illustrated by oscillograms covering a wide range of currents, both with and without power voltage applied.

The size of the new arresters is about one-half that of the present commercial autovalve arresters. One of the probable benefits resulting from this reduction in size is the possibility of making practicable the protection of high-voltage lines against lightning flashover.

* * * * *

PRINCIPLE of Operation of New Arrester. In a paper presented by the authors[3] at the Chicago meeting of the Institute last December, it was shown that the properties of discharges confined to narrow passages are such that good electrical valve characteristics may be obtained by the use of a block of slightly conducting porous material. This is the principle of the new autovalve arrester. Like the old autovalve, it depends for its valve characteristics upon special forms of discharges in gases in which the voltage for maintaining the discharge is kept from falling much below the voltage for initiating the discharge.

Development of New Arrester. The principle of operation referred to above, and described in the authors' previous paper, broadly defines the mechanical and electrical properties of the materials to be used in the structure of the valve element. In the development of the arrester it was necessary, however, to determine the range of materials which is suitable, the permissible range of fineness of these materials, the cross-section and length of the element; also to make a careful study of the effects of variation in the methods of manufacture. The materials selected as the component parts of the porous element are fabricated into cylindrical blocks of the desired cross-section and convenient length. Each one of these then provides a unit with valve characteristics. At the present time, the blocks are made in units rated at 3000 volts maximum, one inch long and two inches in diameter, this cross-section providing sufficient discharge capacities for line type arresters.

In the course of the experimental work, numerous materials were tried and several thousand arrester elements of various types manufactured, these generally consisting of a specially prepared clay which is carefully ground to obtain the proper fineness, with a small amount of conducting material added to initiate the discharges in the pores provided by the granular insulating material. The range of conducting materials which may be used is large. For example, good results were obtained by the authors with metals such as brass, aluminum, iron, nickel, and copper; with ferro alloys such as ferro-silicon, ferro-tungsten, and ferromanganese; with refractories, such as graphite and carborundum; with minerals such as rutile, coal, coke, and many other materials.

The two kinds of material,—namely, conducting and

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*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

3. For all references see Bibliography.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

insulating,—are mixed together thoroughly and pressed into blocks having the proper porosity. If the material is coarse, the cut-off gradient will be quite low, while if it is very fine, the gradient will be high. Studies of this nature revealed that the desirable structure to use in lightning arresters was not the finest which was tried, having a high cut-off gradient. These extremely fine materials as a rule are not so permanent, although it is possible to construct workable arresters with voltage ratios as low as 1.4. Permanent structures, somewhat

FIG. 3—NEW AUTOVALVE ARRESTER ELEMENT

Rated at 3000 volts, after it has been copper sprayed and insulated

coarser and thicker for a given voltage rating, gave ratios around 2.5. This latter type of block was chosen as the desirable one to use in arrester designs at the present time, since its ratio falls within the limits of adequate protection and its size is small.

The preferred shape of element is a cylindrical block, because elements of this kind are simple to manufacture and can be assembled conveniently in porcelain casings of designs which are comparatively easy to make. The thickness of these blocks is proportional to the voltage for which they are intended to be used, and their cross-section may be made to suit the discharge current requirements.

To insure a good electrical contact, the blocks or arrester elements are sprayed with copper on the parallel faces, by the Schoop spray process, leaving a small unsprayed rim near the edges to eliminate the possibility of particles of copper getting on the other surfaces. The cylindrical surface of the blocks is then insulated with a coat of cement to prevent any chance of flashover due to surface creepage, and the blocks are ready for assembling in arresters. (Fig. 3.)

Completely assembled arresters are built up by stacking the blocks one above the other in a porcelain casing, the number depending upon the voltage rating of the arrester. A spark-gap is placed in series with the assembled element.

Electrical Characteristics of New Arrester. Volt-ampere characteristic curves have been made on many of the 3000-volt arrester elements to determine the maximum discharge and cut-off voltages and their ratios with various discharge currents ranging from 12 amperes to about 1100 amperes. These tests were made by means of a Dufour type cathode ray oscillograph used in conjunction with the unique circuit devised by Harrington[4] for simultaneously tripping off the impulse circuit, which is the source of test voltage, and the cathode ray oscillograph, used for measuring arrester performance. The results of these tests can best be explained by referring to the oscillograms shown in Fig. 5. It will be noted that for current densities of the order of about 4 amperes per square inch, the voltage ratio is about 1.8, while for the higher current densities of the order expected from lightning discharges, it is about 2.5. The low-current oscillogram is interesting in that it shows the nature of the cut-off at extremely low current densities. The oscillogram showing only the first part of a high-current characteristic was produced by allowing the cathode beam to go off the film, and is included to give a magnified picture of the cut-off at the higher current densities.

In order that only a small current is permitted to flow through the arrester following the passage of a lightning discharge, the practical arrester as applied to circuits is so designed that the cut-off voltage is close to the crest of the arrester's voltage rating. This small leakage current is interrupted by the series gap. If the cut-off

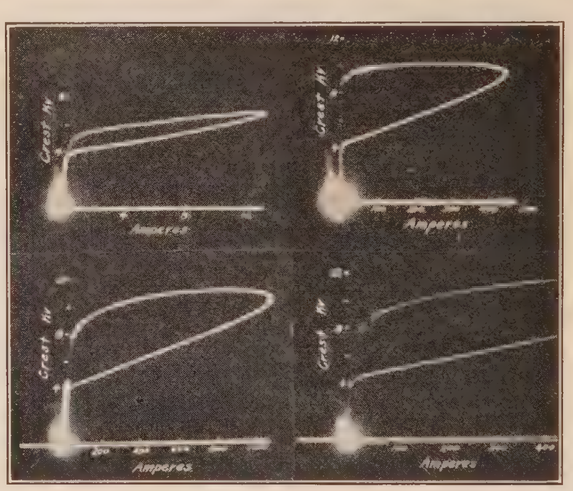

FIG. 5—VOLT—AMPERE CHARACTERISTICS OF 3000-VOLT ARRESTER ELEMENTS WITH VARIOUS VALUES OF SURGE CURRENT

Oscillogram	Voltage ratio	Maximum current density
C-303-AA	1.8	4 amperes per sq. in.
C-303-AC	2.5	140 " " " "
C-303-AE	2.6	320 " " " "
C-303-AH	2.6	350 " " " "

voltage is much less than the rated voltage of the arrester, considerable line current will follow the lightning discharge, the amount depending upon the magnitude of the cut-off voltage. Thus, by maintaining a high cut-off without altering the crest of about 2.5 times the system voltage, the arresters may be made safer against dynamic overvoltage. It is also desirable to keep the cut-off voltage as high as possible so that the volt—ampere loop will be narrow and more energy extracted from the surge as its voltage is decaying.

The sharp cut-off action of the new arresters discussed and illustrated above, by oscillograms covering a wide range of currents, indicates that arresters of this type

should not allow a large power current to follow a lightning discharge when they are connected to a source of power voltage, as they normally would be in practise. In order that this may be checked, oscillograms were taken with arresters connected to a source of power of large capacity whose voltage is equal to that of the maximum ratings of the arresters being tested. An oscillogram obtained in this manner on a 15-kv. arrester is shown in Fig. 6. It will readily be seen that the current which follows the discharge, indicated by the small break in the zero current line, amounts to only a little over an ampere and lasts for a fraction of a half-cycle of the 60-cycle voltage. Currents of this order of magnitude and duration are not sufficient to interfere with the operation of the arrester.

Size of New Arrester. The new autovalve arrester elements are of such small size that a block one inch thick is good for a maximum rating of 3000 volts r. m. s. This has made it possible to reduce the size of arresters, particularly those of high voltage, partly because of the small size of the porcelain casings which are required and partly because of the reduction in size, and in some cases, the elimination of the supporting structures. This reduction in size of high-voltage arresters has made it possible to install arresters in existing substations where space limitations do not permit the application of the arresters now in general use. These new autovalve arresters are light in weight, require little space, are simple of installation and with expense of transportation considerably reduced.

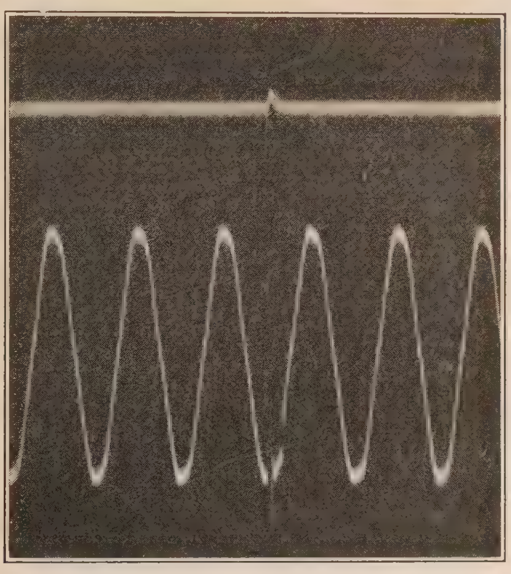

Fig. 6—Oscillogram Showing Power Follow on a 15-Kv. New Autovalve Arrester

Note that the power follow current is only a little over one ampere. This oscillogram should be compared with the volt—ampere curve shown in Fig. 1

The small size of the new arrester is indicated in Figs. 9 and 10, which show the new arrester compared to a present standard autovalve of the same voltage rating.

The reduction in size and weight makes it possible to suspend arresters of this type from the station structure, or even from the transmission line towers, thereby entirely eliminating the requirements for arrester space in a station. This possibility is of particular importance in the field of line protection for high-voltage systems. It has been realized for some time that distributed lightning protection,—that is, the placing of arresters at intervals along a transmission line,—will not only decrease the lightning hazard to station apparatus, but will also greatly reduce the likelihood of insulator flashovers on the line, the degree of reduction effected

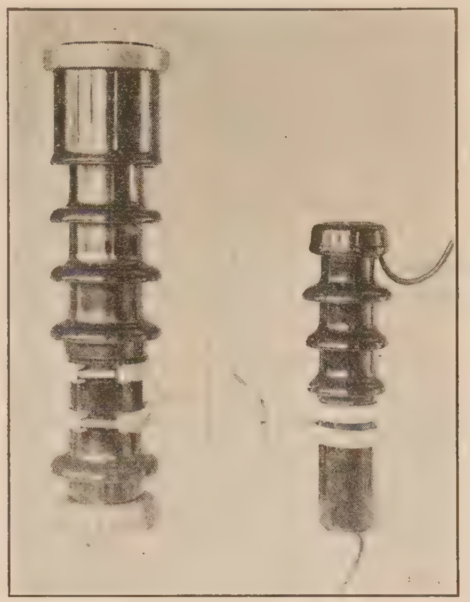

Fig. 9—Comparative Size of 25-Kv. New and Old Line Type Autovalve Arresters

The arrester on the right is the new type.

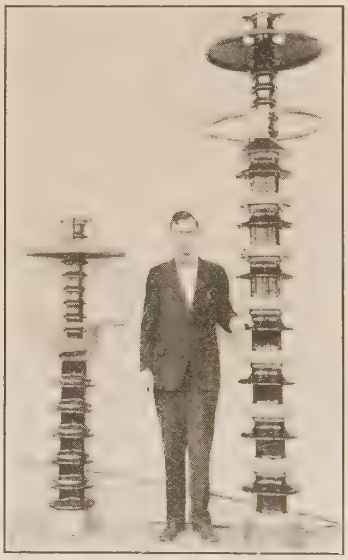

Fig. 10—Comparative Size of 73-Kv. New and Old Station Type Autovalve Arresters

being a function of the density of the distributed arresters. Heretofore such distributed protection has not been considered economically practicable because of the size and weight of the present available arresters. The new valve arresters described in this paper bring this method of protection within the realm of practical use. High-voltage line type arresters of the new construction are little different in size from the strings of insulators generally used. Incorporating arrester elements in insulator strings may be a development of the future.

It may now be economically feasible to increase the reliability of existing lines which suffer from outages caused by lightning flashover by the installation of arrester protection. The effect of an efficient line arrester on construction of new lines may be considerable. Such an arrester, besides reducing the likelihood of lightning outages, permits a reduction in the lengths of the insulator strings now used to increase the reliability of a line. This decrease in insulators in itself involves but a small saving, but the resultant decrease in crossarm spacing and tower height reduces the cost of construction considerably. With impulse voltage data on insulating structures and arrester performance available and with field data on the character of lightning disturbances being accumulated by means of cathode ray oscillographs, it appears that in a short time it may be practicable so to rationalize the insulation and protection of a system that lightning outages will be reduced to the optimum economical minimum.

A number of installations of high-voltage line type arresters has been in service during the past season, chiefly for the purpose of determing the degree of benefit actually obtained in reducing line flashovers, and to secure operating data on the desirable spacing of arresters for this purpose. Fig. 13 shows the type of arrester used, and its method of mounting.

Arrester Installations and Experience. Exhaustive laboratory tests on the new valve arrester at the factory has thoroughly proved its remarkable performance; however, since laboratory experience must be substantiated finally by successful results in service, it was thought desirable to place a number of these arresters in service in the field as a final verification of their performance. Tests of this type offer the only opportunity to gain operating experience with arresters connected to complicated networks providing a multiplicity of circuit conditions which can be reproduced only in part in the laboratory.

Such a procedure is always advisable before any new piece of electrical apparatus is produced in large quantities, since it gives the manufacturer an opportunity to correct minor defects or make additional improvements in the final design while the field tests are progressing on a comparatively small scale.

In order that the maximum number of operating conditions might be secured, due partly to differences in the behavior of electrical systems themselves and partly because of atmospheric variations such as differences in altitude and the amount and kind of impurities contained in the air, numerous arresters were installed in all sections of the country, both on grounded and ungrounded electrical systems of various voltages. The first of these arresters were installed on a 2300-volt system about August 1, 1928. Other installations with higher voltage arresters rapidly followed; these included station type arresters of 73-kv. rating, until by the end of 1928, over 1200 arresters had been placed in the field. Additional installations were made during 1929, and by the end of the lightning season, over 1500 additional arresters had been placed in service, including high-voltage line type arresters and station arresters of 132-kv. rating. The arresters installed to date include all voltages from 3 kv. to 132 kv., and thus represent a wide range of operating conditions. These field tests will be continued.

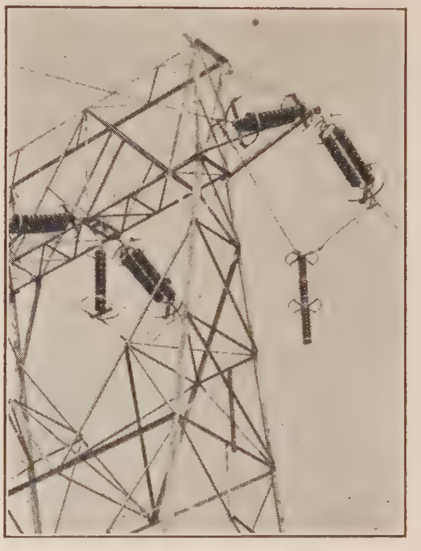

Fig. 13—One of the New Arresters Suspended from One Phase of a 110-Kv. Transmission Line

The installation in this case was made at a substation to serve both for line and station protection

Thus far, with over 2500 arrester years of service experience, the operating record has been remarkably good. There have been a few disputable cases of small low-voltage transformer failures. A few arresters of the lower voltage classes have been damaged because of mechanical defects which only service experience will reveal and remedy. Out of a total of 200, one high-voltage line type arrester was damaged, apparently due to a close-by direct stroke, as a klydonograph connected to another phase of the same circuit at the same location was destroyed at the same time.

Such a service record, it is felt, has been encouraging and has undoubtedly established the permanence of these new valve type arresters.

Conclusion. This development has made possible arresters of reduced size. At the same time it has brought about performance improvements. As a

result of the size and performance improvements, it makes practical for the first time the protection of high-voltage transmission lines.

In conclusion, the authors wish to thank Messrs. A. L. Atherton and E. Beck for the strong support they have given during the development of the new autovalve arrester, as well as for their valuable suggestions in the preparation of this paper. Others whom the authors wish to thank for the aid they have given in suggestions or in making tests include Messrs. A. M. Opsahl, H. M. Kraner, M. E. Gainder, R. A. Wycoff, and L. R. Smith.

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Abridgment of

Induction Motor Performance Calculations

BY P. L. ALGER*

Fellow, A. I. E. E.

Synopsis.—*By means of solutions of the induction motor exact equivalent circuit in the form of infinite power series, approximate formulas for the important motor characteristics are derived. These formulas enable the effects of magnetizing current, core loss, and primary resistance on maximum torque, starting current, and so forth, to be readily taken into account with engineering accuracy. A new form of power-factor chart is presented, which permits of the power factor–load curve of any motor being conveniently determined from no-load test data. Exact values of power factor can be obtained from the chart by applying differential corrections, for which formulas are given.*

The methods outlined were developed to secure an optimum combination of speed, accuracy, and consistency in design calculations, and have been in regular use for the past seven years.

THE performance of an induction motor can be quite accurately determined if its starting current, running light current, and its friction, windage, core, and copper losses are known. Each of these quantities affects in some measure the motor's performance in regard to efficiency, power factor, and torque, so that to take accurately into account the influence of all these factors in designing a motor involves a great deal of labor.

It is therefore customary in text books and in approximate design calculations to consider only the most important factors in calculating each particular characteristic of the motor, in this way obtaining simple formulas. For example, the maximum running torque of a motor is generally considered to be inversely proportional to the motor's leakage reactance, or nearly proportional to the motor's starting current; but the influence of the running-light current on the maximum torque is normally neglected except in refined calculations.

Recently Mr. W. J. Branson[1] presented a paper before the Institute, in which he described the preparation of a series of about 100 charts, from which, when the motor's constants are known, the motor's performance characteristics can be read off. Because of the large number of motor constants which have to be taken into account a large number of charts is required.

The present paper attacks the problem in a different way, with the object of obtaining relatively simple algebraic formulas for polyphase motor performance characteristics by means of relatively small correction terms added to the usual approximate formulas. These correction terms are obtained by solving the equivalent circuit (Fig. 1) of the motor in the form of an infinite series in ascending powers of the per unit motor reactances and loss factors. While the results obtained in this way are approximate, nevertheless formulas are obtained which are amply accurate for practical design work. Also, the formulas have the advantage of showing up the independent effects of each of the motor constants, thus enabling the interrelations of the various constants and the characteristics to be clearly seen.

In this way, formulas are obtained in terms of readily measurable motor constants for the starting current, starting torque, maximum torque, secondary resistance, and other important characteristics. It is found that the product of the per-unit magnetizing current and per-unit leakage reactance drop, which corresponds to the well-known leakage factor, and which is represented in the paper by the symbol $a\,b$, is very useful in the calculations. For example, it is found that if the complete performance of an ideal motor with zero running-light current is obtained, expressed in algebraic formulas as is usually done in text books, the following correction factors should be applied to the results to get the true values with engineering accuracy.

The maximum torque and maximum output should each be multiplied by $1 - \dfrac{3\,a\,b}{4}$.

The starting torque should be multiplied by $1 - \dfrac{a\,b}{2}$.

*General Electric Company, Schenectady, New York.

1. For references see Bibliography, complete paper.

Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Complete copy upon request.

The starting current should be multiplied[4] by $1 + \frac{a\,b}{4}$.

The formulas obtained in this way for power factor are not sufficiently accurate for practical purposes, but the same method was used to obtain results in a different way. Definite values of the loss constants for a typical motor were assumed, and with these values, a chart (Fig. 3) showing the power factor against load for motors having a wide range of values of the leakage factor was calculated. Knowing simply the running-light current, the reactance of the motor at starting, and any assumed load current, the power factor and the power-factor load curve of any motor can be immediately taken from the chart. Formulas for differential corrections to be applied to the chart readings are then developed in terms of the motor loss constants, which enable accurate values to be obtained from the single chart, whatever the motor characteristics. The results read directly from the chart are accurate to within about 1 per cent for ordinary motors, but they may be in error by 2 or 3 per cent for motors with extremely high or low efficiency. By use of the correction terms, however, results accurate to within 0.3 of one per cent can be obtained for almost any polyphase motor.

Summarizing the whole, the paper gives correction factors to be applied to the elementary text book induction motor formulas, which enable the effects of magnetizing current and loss constants of a polyphase motor to be taken into account with engineering accuracy. And a new form of power-factor chart is shown, permitting the power factor of any motor to be readily obtained from the simplest of test data.

Abridgment of

Operating Characteristics of Turbine Governors*

BY T. E. PURCELL† and A. P. HAYWARD†
Non-Member Non-Member

***Synopsis.**—Surging has occurred on power systems whose transmission distance is small and load density high. The Duquesne Light Company of Pittsburgh, Pennsylvania, has experienced these surges. This paper outlines tests conducted to determine the influence the steam turbine governors have in starting or sustaining a surge condition. The conclusions assumed are:*

1. The governor system installed at Colfax Power Station will not start system surging.

2. The governor system will not sustain load oscillations.

* * * * *

Introduction

On several occasions, the system of the Duquesne Light Company of Pittsburgh has developed periods of severe surging. During these surges, indications have been that one or more generators were out of synchronism for periods of time lasting from a few seconds to several minutes. These surges have sometimes followed severe faults on the 66-kv. transmission system, the generators apparently drifting apart during the low-voltage period, resulting in severe surges during recovery of voltage and at other times have followed the loss of excitation due to exciter failure or regulator action.

The Duquesne Light system (Fig. 1) has two major power stations located approximately 18 mi. apart. These stations are connected by a 66-kv. ring transmission system. Colfax Power Station of 260,000-kw. capacity supplies all of its output to the ring at 66 kv. This power is transmitted through the ring to various step-down substations which feed the distribution substations at 22 kv.

Brunot Island Power Station of 116,000-kw. capacity is located near downtown Pittsburgh. This station and the 66-kv. transmission ring are paralleled on an 11-kv. bus from which the power is distributed mainly through an 11-kv. cable system.

The original turbine governors at Colfax Power Station were of the flyball type with a single oil relay actuating the primary valve mechanism. A system disturbance causing loss of a major portion of the Colfax load would result in the operation of the overspeed trips on the turbines, resulting in loss of the entire load.

The governors at the Brunot Island Power Station are of the same type. Due to the large number of 11-kv. feeders and bus reactors preventing a major loss of load, faults on a section near Brunot Island do not cause severe overspeeding.

The present governors installed at Colfax Power Station are the result of much experimental work on the part of the Westinghouse Electric & Manufacturing Company and Duquesne Light Company engineers. As a result of many load dumping tests,[1] the governors were finally modified from the original type to the present type, which consists of the flyball mechanism, an oil relay, which in turn actuates a larger oil relay, giving the force to the mechanism of the primary valve. To insure an adequate supply of oil at constant pressure during the period when the primary valve relays were

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*Part IV of a Symposium on Power System Planning.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

1. For references see Bibliography.

operating, oil accumulators were added to the governor oil system. The net results of these changes have been to reduce the load on the flyball governor when tending to correct the valve setting and insuring an adequate oil supply to carry through the movement required for a change in speed conditions. The reduction of duty on the flyballs has resulted in a much faster and more accurate following of the speed changes, allowing the

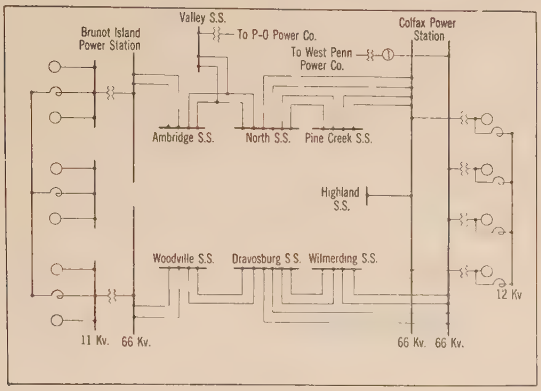

FIG. 1—SCHEMATIC DIAGRAM OF TRANSMISSION SYSTEM

governors to hold the turbines below the limit of the auto-stop setting.

It was the purpose of the tests described in this paper to determine the effect of the governors during observed periods of surging. The following tests were set up to either reproduce or indicate the true action of the governors.

The determination of the effect of the governors during periods of severe surging involved the knowledge of the natural period of oscillation of the governor system and the natural period of oscillation of the complete system. The first series of tests was conducted with a view to determining the natural periods of the turbine governors, the second series, the natural period of oscillation of the complete system, *i. e.*, the combined turbo generators and transmission system, and the third series the action of the turbine governors during a period of surging (pole slipping) of a main generator. During many of the severe disturbances, one or more of the main generators have been observed to be pole slipping or give indications which would lead one to believe that if the system had not been sectionalized pole slipping would have resulted. All of the tests were conducted at the Colfax Power Station.

Colfax has ten generators ranging from 23,600 kv-a. to 48,500 kv-a., grouped in four units. Units Nos. 1 and 2 each consist of a high-pressure turbine, exhausting to two low-pressure turbines, each having a generator of 23,600 kv-a. connected to it. The high-pressure turbine governor normally controls the load for the entire unit. Units Nos. 3 and 4 each have two single-shaft turbo generators of 35,300 and 48,500 kv-a. respectively, Unit No. 4 having the oil relay type of governor.[2]

Brunot Island has seven generators, five single-shaft turbo generators with a capacity of 18,000 kv-a. each and one cross-compound of 47,200-kv-a. capacity. Each element of the compound unit is rated at 23,600 kv-a.

The natural period of the governor was found in the following manner. A turbo generator was loaded to a predetermined value varying from one-quarter to full load. With the load adjusted and all other conditions normal, the turbine operator would grasp the governor sleeve linkage and depress it until the load on the machine had increased approximately 10,000 kw. beyond the load setting of the governor. The governor flyballs would then adjust themselves to counteract the external force applied, and the primary valve would adjust itself to a new position. The release of this external force resulted in a change of position of the flyballs, creating a tendency in them to oscillate about their new position until a state of equilibrium had been reached. This change in governor position reduced the amount of steam delivered to the turbine, resulting in a load swing on the generator. It was believed that if this load swing on the generator and the natural period of oscillation of the turbine governor corresponded in the proper phase and time, it would be possible for such a disturbance to amplify itself to such a degree as to cause the generator either to pole-slip or start severe surging of the entire system.

An oscillograph was used to record the oscillation and power output of the various units during the test.

Slide wire potential dividers were connected to the governor sleeves and primary valve pistons of all typical units in the station. The movement of the various parts resulted in a change of potential across a

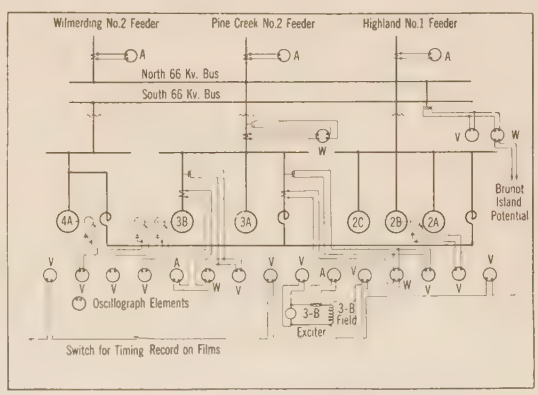

FIG. 6—SCHEMATIC DIAGRAM OF OSCILLOGRAPH CONNECTIONS —GOVERNOR OSCILLATION TESTS

circuit which being connected to an oscillograph element would properly record the increment. Other quantities recorded were single-phase output, bus voltage, and field amperes of the generator under test. The set-up was so arranged that the action of the governor on one unit might be recorded on the same film with the corresponding reaction of the governors on the adjacent units, (Fig. 6).

The results of these tests indicated that on Units Nos.

1 and 2, the governor period varied from 100 to 135 cycles per minute and the load swing period, from 80 to 87.8 cycles per minute. Units Nos. 3 and 4 indicated an average period of 143 cycles per minute for the governor oscillation and 62.2 cycles per minute for the load swing. The discrepancy between the period of the load swing for Units Nos. 1 and 2 and Nos. 3 and 4 can be accounted for by the difference in moments of inertia of

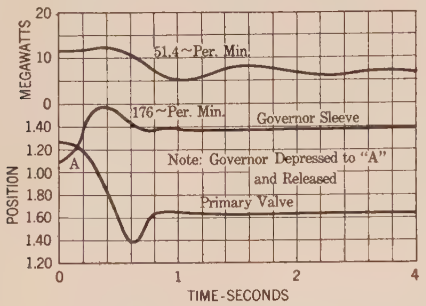

FIG. 7—GOVERNOR PERIOD TEST—3-B ELEMENT

the revolving masses. The moments of inertia of 1-B and 2-B are 220,800 lb-ft.,^{2} 3-A and 3-B have a moment of inertia of 560,000 lb-ft.,^{2} and 4-A and 4-B have moments of inertia of 586,000 lb-ft.^{2}

The ratio of the governor period of oscillation to the load oscillation for Nos. 1 and 2 is 1.45 to 1. For Nos. 3 and 4, the ratio is 2.3 to 1. In order that one system may support an oscillation in another system, the two must be in resonance; that is, having the same period. Also, the two oscillations must have a phase displace-

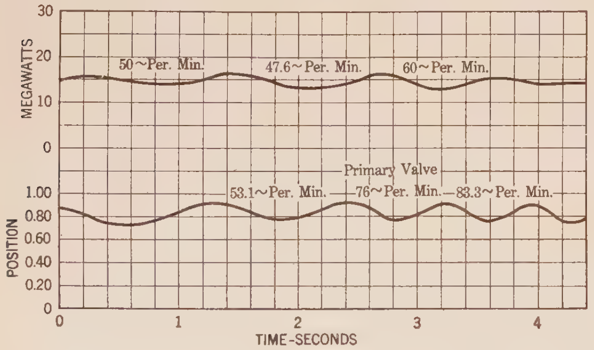

FIG. 8—CURVES OBTAINED ON SYSTEM OSCILLATION TESTS

ment of 180 deg. If the natural period of the governor is the same as the natural period of the rotor, and the time lag between the governor action and the effect of the steam on the rotor equals one-half of this period, this condition can be met on the turbine. If it is assumed that the governors oscillate at their natural period, the effect on the turbine due to the variation in steam flow would not tend to sustain oscillation of the generator output, due to the difference in frequency between the governor and rotor periods. Also, the tests indicate that the governor mechanism comes to its position of equilibrium after an impulse within one and a half cycles of governor oscillation. (Fig. 7.)

The second series of tests was devised as a means of checking the natural period of the complete system. A device was constructed and installed on element 3-B which replaced the link between the primary valve oil relay and the link from the governor oil relay. This arrangement allowed the primary valve to be moved from one extreme to another independent of the governor setting or condition on the governor system. It was believed that if a load oscillation having the same frequency as the complete system could be established on one of the main units, surging would result and could be readily recorded. The possibility of introducing on the system a surge which might result in a major disturbance was considered. To avoid this, the oscillator mechanism was constructed so that both the load swing and the frequency of the swing could be manually controlled. The test was conducted by introducing a load swing of approximately 10,000 kw., the frequency of this swing being varied from 30 cycles per minute to over 130 cycles per minute.

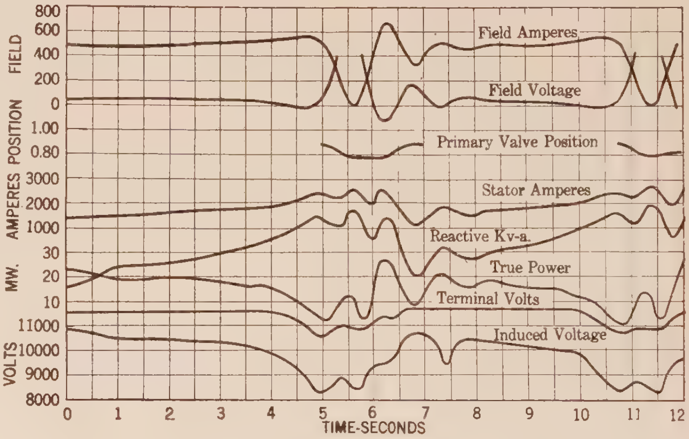

FIG. 9—CURVES OBTAINED FROM POLE-SLIP TEST

The same set-up records were obtained on this test as on the previous one, but in addition, oscillographic records were made of transmission line current and phase angle between the two generating stations. It was not possible to create sufficient disturbance to oscillate the system. The tests, however, did indicate that the generator output closely follows the steam input from low frequency, until the variation in the primary valve movement reaches a period of from 60 to 70 cycles per minute. Above this frequency, the amplitude of the swing decreases until at approximately 100 cycles per minute, the steam variation becomes too fast to affect the output (Fig. 8). This point checks the statement made as a result of the previous tests, that if the governors did oscillate, their period would be too fast to have any appreciable effect on a load swing.

The third series of tests was conducted to determine the governor action during pole-slipping of a main unit. The resulting system disturbance was recorded with records of field amperes, field voltage, stator amperes, single-phase watt output, transmission line current,

high-tension bus voltages, phase angle between generating stations, and governor action on adjacent units. The pole-slipping was accomplished by adjusting the field current until the generator, at full rated load, had unity power factor. The field was then gradually lowered by means of the face-plate rheostat until the current from the stator tended to increase at a rapid rate, indicating the start of a pole-slip, when the field was given a slightly lower value and all adjustments discontinued. During the pole-slipping, approximately one-third to one-half of the field rheostat was in series with the field. In every case of this nature, the first pole-slip would take place very slowly; then there would be an appreciable time or interval during which no surging would occur; then a second slip would take place. The third slip would occur at a shorter interval,

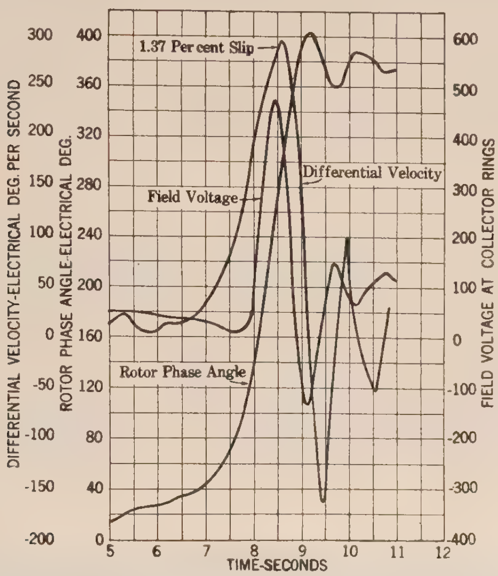

Fig. 10—Analysis of Phase Angle between Induced Voltage and System

the period gradually decreasing, (Fig. 9). During operations of this type, strengthening of the field during the period of steady operation resulted in the machine's pulling into step and remaining in step. By trial, it was also found that tripping the turbine throttle allowed the generator to pull into step. The torque produced by the turbine having been removed, the generator synchronizing torque, notwithstanding its weak field, was sufficient to pull the rotor into step with the system and continue to operate in synchronism. Two factors were determined; first, that a large turbo generator out of synchronism may be pulled back onto the system without a reduction in throttle setting by carefully increasing the field current at the proper time, provided the surging has not become too rapid; second, that a generator which is pole-slipping may clear itself of that condition if the turbine torque is removed or reduced.

The oscillographic records substantiated observations, proving that during pole-slipping, the power factor changes from lead to lag. This is true of a distributed field turbo alternator and is caused by the induction generator effect which prevents the power output from approaching zero during pole-slipping conditions.

Of the records obtained during the pole-slipping tests, those showing the angle between the rotor and the field of the stator are of interest. (Fig. 10.) An analysis of this displacement angle gives an indication of the rate of change of speed of the rotor during the pole slipping period. Also, when compared with the kw. output from the stator and the position of the primary valve, it gives a very definite indication of the true governor action during pole-slipping of the unit.

From the oscillograph records, it appears that there is a positive power output at the time of maximum slip or differential velocity between the stator field and the rotor, and at this instant, the governor valve is at its minimum opening. The maximum power output, however, occurs at the instant the rotor passes through its next in phase position. At this instant, it is seen that the governor valve is just beginning to open. This condition indicates that the governors on the turbines follow the speed changes caused by pole-slipping and attempt to reduce the steam input. Therefore, it seems that the governor, by reducing the torque, will allow the generator to pull back into step and attempt to recover its load; but if at this instant the cause of the original disturbance has not been removed, the generator will again pole-slip.

Conclusions

The periods of the governor oscillation and load oscillation on the generators do not have a time phase that would sustain a surge.

The natural governor period is sufficiently fast to eliminate the effect of the variation in steam input on the load output.

The governors are sensitive enough to hold the turbine from overspeeding, and tend to check the speed of the turbine during a pole-slip.

The above conclusions are based on observations during a staged test. From these tests it seems fair to assume that on the turbo generators at Colfax, the governor oscillation can have no effect on the load output and the oscillation frequency of the load and governors are so far apart that the governor will not assist in sustaining a surge.

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Successive Unidirectional Condenser Discharge

BY SHIRO SANO[1]

Associate, A. I. E. E.

Synopsis.—A phenomenon of successive unidirectional discharges of a condenser across a gap placed between its terminals, when the condenser is connected in series with an inductance having such constant that resonance occurs in the system when supplied with alternating e. m. f., is described. An ordinary sphere-gap does not give stable operation for any length of time. A special form of gap which gives satisfactory operation is described. Direct current may be obtained from the system if a proper wave-filter is utilized. Finally, the application of the system as a generator of successive unidirectional voltage impulses is discussed.

When a condenser is connected in series with an inductance, and an alternating current of such frequency is applied to the extremes of the two that resonance occurs, a surge of energy will manifest itself between the inductance and the condenser. When the system is started from a dead condition, the surging energy between the condenser and the inductance must be supplied from the supply circuit and thus cannot attain its final value instantaneously. A

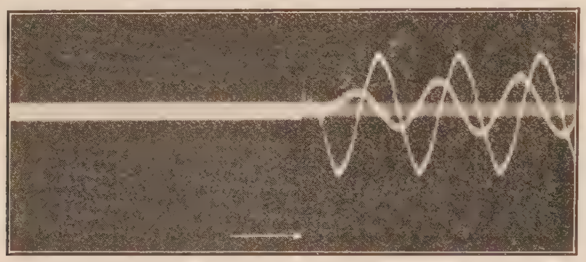

Fig. 1—Showing Growth of Potential Difference at Condenser Terminal when Alternating E. M. F. is Applied to System

cumulative oscillating growth of the surge energy, current, and e. m. f., is thus to be expected. Fig. 1 shows a gradual growth of the potential difference at the condenser terminals when an alternating e. m. f. is suddenly applied to the extremes of the resonating system. It will be revealed from the figure that even at the very beginning of the growth the potential difference at the condenser terminals, V_3, is in quadrature with the supply e. m. f., V_1.

If the terminals of the condenser are connected to an air-gap and the gap length is so adjusted that it will break near the crest of the second half-wave of condenser voltage, which is always greater than that of the first half-wave, the condenser will be discharged near the second crest but not at the first. By the time the discharge of the condenser is finished, the whole system is brought to the initial condition and a fresh start recurs with the finish of the discharge. It can be shown that the recurring discharges are at the same phase of the wave; that is, near the crest of the second half-wave of condenser voltage in the case above cited. The successive unidirectional discharges of the condenser are thus made manifest.

If the gap is brought to a longer separation, so that it breaks near the crest of the fourth half-wave, the discharge will occur once in every two cycles of the supply e. m. f., as is shown in Fig. 2, in which V_2 represents the potential difference at the condenser terminals, V_1 the supply e. m. f., and V_3, the voltage over a resistance in the discharge circuit. The figure shows the discharge over an ordinary sphere-gap which is connected in series with a resistance sufficiently high to make the discharge non-oscillatory.

If, on the other hand, the gap is so adjusted that it breaks near the crest of the third half-wave, the discharge will be alternating in direction.

An interesting fact is, that at the instant the condenser discharges at a crest of the condenser voltage, the supply e. m. f. and current are both at their zero value. Besides, all the surging energy in the system will have been stored in the condenser and none in the magnetic field of the inductance at this instant.

An air-gap however, is not so simple in its nature, as to allow the successive discharges in one direction without failure; that is, it is more or less erratic. Experience shows that the operation of the ordinary sphere-gap is steady only for a short while, and a slight irregularity in the gap or elsewhere causes the condenser to discharge in the opposite direction.

The author has devised a special form of the gap

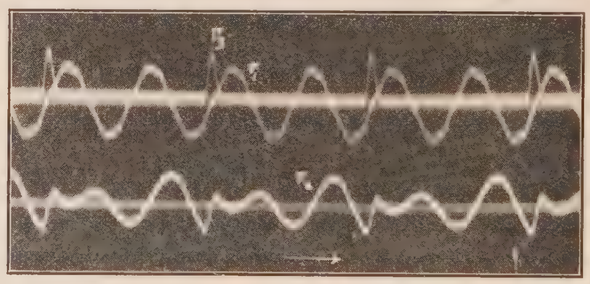

Fig. 2—Showing Discharge Once in Every Two Cycles of the Supply E. M. F. with Spherical Electrodes

which eliminates the erratic nature so completely that successive unidirectional discharges of the condenser are insured. As one pole of the gap, the author has selected a cylinder with spherical head, made of an easily volatile metal, such as zinc; as the other pole, a wire of suitable diameter with high melting point, such as platinum, has been used. Owing to the bombardment of positive ions issuing from the zinc pole, with a few preliminary discharges, the tip of the platinum wire will be heated to a high temperature, and a swarming cloud of electrons be liberated from the platinum tip and supplied to the gap. Thus to a certain degree the

1. President, Sano Electric Manufacturing Co., Tokyo, Japan. *Printed complete herein.*

gap is endowed with unidirectional conductivity. Experiment shows that under this condition, the discharge is highly stable and a wide change in the gap length does not make even a flicker.

The operation of this form of gap without the resonating system, however, shows that the current is not unidirectional, but is alternating, even at the highest temperature endurable with platinum. Thus the gap in itself is not to a high degree unidirectional, but a resonating system is required in connection with it to give a satisfactory operation. Fig. 3 illustrates such a gap in actual operation; a core of white heat is surrounded by a halo of haze.

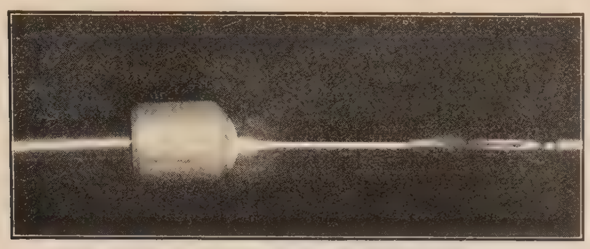

Fig. 3—Special Spark-Gap which Gives Steady Operation

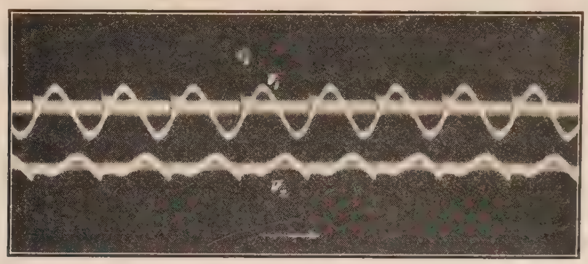

Fig. 4—Showing Discharge Once in Every Cycle of the Supply E. M. F. using Circuit of Fig. 5 and Special Gap

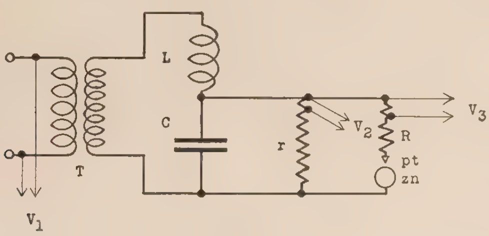

Fig. 5

Fig. 4 gives an example of successive unidirectional discharges of the condenser over a resistance in a circuit shown in Fig. 5; V_1, representing the supply voltage, was taken from the primary side of the step-up transformer, T, and the voltage on the condenser, V_2, was taken across a part of a very high resistance, r; V_3 was taken over a portion of resistance of the load, R, as shown in the illustration. It will be seen that the discharge occurs a little before the supply e. m. f. reaches its zero value, and considerably before the condenser voltage assumes its crest of the second half-wave—(rather the third half-wave in this particular case). The voltage at which the gap is ruptured does not appear to be any higher than the crest of the preceding half-wave, and it seems to show that the gap works as a unidirectional path to at least a certain degree. The wave front of V_3 is shown to be very sharp,—really precipitous. If the gap length were much greater, the voltage at which the discharge occurs would have been higher than the crest of the preceding half-wave, as is the case with Fig. 6.

This figure illustrates a case when the condenser discharges through a circuit consisting of the resistance

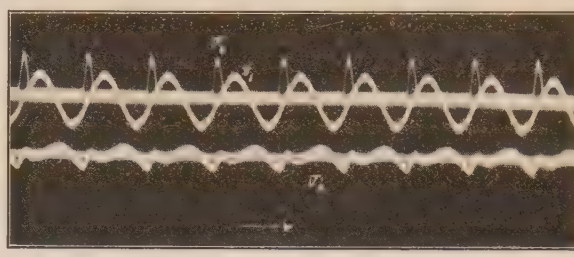

Fig. 6—Showing Condenser Discharge through Resistance and Inductance in Series

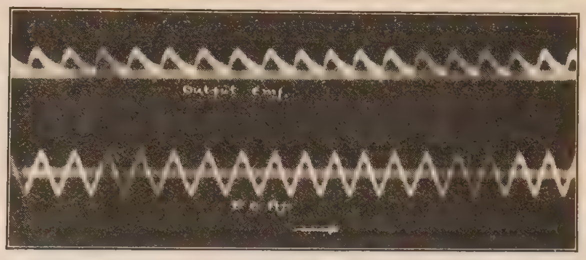

Fig. 7—Showing Condenser Discharge with Circuit Shown In Fig. 8

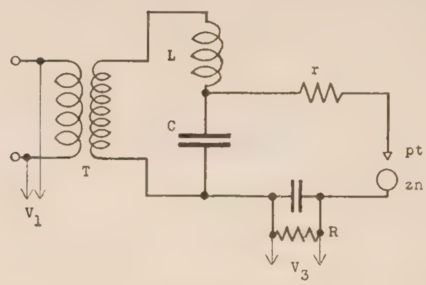

Fig. 8

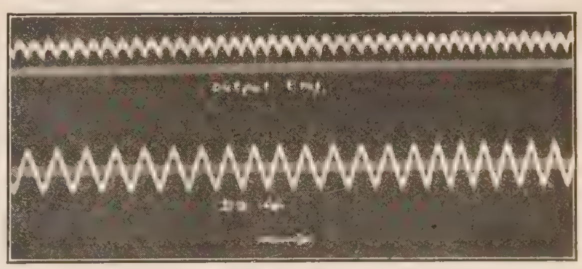

Fig. 9—Showing Double Rectification

and the inductance connected in series, and the voltage V_3 was taken over a part of the resistance. It will be seen that the wave front of V_3 is very blunt and that the condenser commences to discharge at the third half-wave at a point higher in voltage than the crest of the preceding half-wave; otherwise, the nature of the discharge is much like that shown in Fig. 4.

Fig. 7 shows the wave front of V_3 in the circuit illustrated in Fig. 8, in which the condenser discharges to another condenser with a resistance shunted, a second resistance, r, being inserted in the circuit to make the discharge non-oscillatory. The wave front of the output e. m. f. is seen to be very slack, and the succeeding waves are so overlapped that a direct current may be obtained when it is connected to a proper wave filter. Fig. 9 illustrates another case in which two circuits similar to that shown in Fig. 8 are connected in parallel so that both positive and negative half-waves of the supply e. m. f. are utilized in proper direction. The figure reveals that the frequency of the ripple is double that of the preceding case and thus is very well suited to obtain direct current through the use of the filter.

By the proper choice of the circuit constants, the form of wave front may be changed at will, and the crest value of the impulse voltage may be changed by the change of the gap length, the longer gap giving greater voltage. The range of voltage adjustment by the change of the gap length is found to be about 100 per cent, so that convenient adjustment of voltage may be made without changing the supply e. m. f.

So far, the condenser is discharged directly through the load, but the arrangement may be so changed that the terminals of the inductance, in lieu of the condenser, are connected to the load. In this case, the condenser is discharged through the outside circuit, the load and the inductance being connected in parallel. The wave form of the discharge current is complicated accordingly.

Thus the system may be used as a simple generator of successive unidirectional voltage impulses in which the wave front may be changed at will by the proper choice of constants in the discharge circuit, and in which the peak value of the impulse may be changed at will within wide range, without changing the supply e. m. f.

Abridgment of

Transient Torque-Angle Characteristics of Synchronous Machines

BY W. V. LYON* and H. E. EDGERTON*
Associate, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*Mechanical oscillations of synchronous motors following the application of abrupt shaft loads have not heretofore been easily calculated for cases of large angular swings, taking into account the damping currents in the rotor, except by tedious point-by-point methods. The chief difficulty has been due to the form of the basic differential equation upon which the solution of hunting problems depends.*

Within the last few years, Doctor V. Bush and others at the Massachusetts Institute of Technology have devised the integraph which is capable of solving the equations of the synchronous motor. Into the integraph are put curves representing the non-linear differential equations and the boundary conditions. The desired results come from the integraph as curves.

In this paper, the problem of sudden load on the non-salient pole alternator is solved by the integraph for enough different conditions so that the performance of practically any machine of this type may easily be predicted from the compiled results. Knowing the moments of inertia of the machine and its load, the characteristics of the machine running as a synchronous motor and as an induction motor, the maximum amount of sudden load for which the machine will remain in synchronism may be determined for different values of initial load. Other curves give the maximum angle of the first swing of the rotor and the time interval for the rotor to change from its initial position to this maximum angle.

The simplest type of equation representing an ideal synchronous machine is solved in this paper. The integraph is capable of solving problems of a much more complicated nature than those presented. The more complicated problems pertaining to machines with unsymmetrical excitation and salient-pole rotors will probably be the subjects of future papers.

INTRODUCTION

THE transient angular oscillations of synchronous machines are important to operating engineers, and within the last few years a number of papers devoted to this subject have appeared in our technical literature. Readjustment of steady-state operating conditions following changes of load or circuit causes the rotors of synchronous machines to swing in accordance with the dictates of mechanical and electrical requirements. The differential equations representing the constraints on the motions of the rotor have heretofore been unsolvable except by means of step-by-step analysis. The development of the integraph has made possible the solution of problems of the type encountered in studies of transient angle characteristics of synchronous machines. It will also be shown how the electromagnetic torque may be computed by the application of a well-known physical principle which heretofore has been little used for this purpose.

In this first paper there will be considered only the simplest case, and therefore the following conditions will be imposed: The air-gap will be considered uniform and the permeabilities of all portions of the magnetic circuit treated as constant,—*i. e.*, the effects of saturation will be neglected. Both the armature and field circuits will be taken as symmetrical, with the windings so arranged that the space harmonics in the air-gap flux become negligible. The problem to be treated specifically is that of the sudden application of

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

load to the shaft of a synchronous motor which is supplied with power from a balanced polyphase source of constant potential and frequency. In this problem, the mutual inductance between the armature and rotor is the only circuit parameter which is variable.

If it be permissible to assume that both the hysteresis and eddy-current losses vary directly with the frequency and the square of the maximum flux density, these losses may be taken into account by assigning the proper complex values to the self- and mutual inductance. This, however, is a refinement which has been disregarded in the computation presented here.

The equation which determines the angle characteristics of a synchronous machine is

$$J \frac{d^2\,\theta}{d\,t^2} + T_{em} + T = 0 \qquad (1)$$

where the first term represents the acceleration torque; the second, the electromagnetic torque developed between the stator and rotor; and the third, the mechanical torque on the shaft, including friction. J is the moment of inertia and θ is the displacement angle of the rotor from some normal synchronous position.

It is first necessary to determine the expression for the electromagnetic torque. In addition to the conditions already assumed to exist, the currents in both the armature and field circuits are considered to be independent of the acceleration; that is to say, the currents at any moment are the same as would flow if the speed at that moment were to exist indefinitely. This additional assumption simplifies the problem. Results obtained with an induction motor having a rotor winding excited with direct current appear to justify this assumption for those cases in which the time constants of the stator and rotor windings are relatively small or the moment of inertia large enough to assure small acceleration.

Equation (**19**) of Appendix I is a complete expression for the electromagnetic torque developed by the motor as a function of the terminal voltage V, the excitation voltage E_1', the armature resistance r_1, the rotor resistance r_2, the synchronous reactance x_s, and the slip. The derivation of this equation, which is based upon the principle of superposition, is given in Appendix I. By this method, the effects produced by the potential applied to the stator and that applied to the rotor are each found separately. Combination of these two effects gives the resulting conditions that exist in the motor. By neglecting the armature resistance r_1, the equation for the electromagnetic torque can be reduced to the form given in (**20**). This expression now substituted in 1, gives

$$J \frac{d^2\,\theta}{d\,t^2} + \frac{1}{(1)} \left[\frac{|E_1'|\,|V|}{x_s} \sin\theta + \frac{1}{360\,f} \frac{|V|^2}{r_2} \frac{d\,\theta}{d\,t} \right] + T = 0 \qquad (2)$$

Since a power equation is more convenient than a torque equation, the above can be put in the power form by multiplying by unit speed (1), giving

$$P_j \frac{d^2\,\theta}{d\,t^2} + P_d \frac{d\,\theta}{d\,t} + P_m \sin\theta = P \qquad (3)$$

Abrupt Application of Shaft Load

The particular problem considered in the integraph solutions of Equation (**3**) is that of the abrupt application of load to the shaft of a synchronous motor. Of especial interest is the maximum amount of abrupt load that can be suddenly applied without resulting in a loss of synchronism. This critical load will depend upon the relative sizes of the coefficients of Equation (**3**) and upon the initial load that exists when the sudden load is applied. It will depend also upon the initial acceleration and slip. Both of these last two factors have been considered to be zero in the integraph solutions. Such a consideration implies that the motor is operating in a steady-state condition at the time when the abrupt load is applied.

The load as a function of time for this specific problem is of the form,

$$\mathrm{P} = P_o + P_L\,\mathbf{1} \qquad (5)$$

where P_o is the initial shaft load.
P_L is the abrupt shaft load.
1 is Heaviside's unit function which indicates that the quantity to which it is applied is zero before time equals zero and thereafter is multiplied by one.

Substituting (**5**) in (**3**) gives (**16**), the complete differential equation including the initial conditions for the problem of abrupt shaft load, it being understood that the initial acceleration and slip are equal to zero.

$$P_j \frac{d^2\,\theta}{d\,t^2} + P_d \frac{d\,\theta}{d\,t} + P_m \sin\theta = P_o + P_L\,\mathbf{1} \qquad (6)$$

From this equation it may be seen that there are five factors which influence the solution. The first factor, P_j, depends upon the combined inertia of the motor and its connected load, and upon the synchronous speed of the motor. The next factor, P_d, depends upon the induction motor characteristics of the synchronous machine when its field circuit is symmetrical[1] and short-circuited. For small values of slip it is approximately proportional to the slope of the slip-torque curve. Actually the coefficient P_d is not constant but is the variable factor which, when multiplied by the slip, gives the correct value for this torque term. The third factor P_m depends upon the synchronous motor characteristics. It is the pull-out power or maximum load that does not cause the motor to pull out of step if slowly applied. The fourth factor, P_o, is the initial load. The last factor, P_L, is the abrupt load that is applied at $t = 0$.

1. This type of rotor was used in the experimental tests.

By a change of time scale, the factors that influence the solution may be reduced to three:

1. $k = \dfrac{P_d}{\sqrt{P_m P_j}}$ = a "relative damping coefficient" which depends upon the induction and synchronous motor characteristics and the combined inertia of the motor and load.

(Although k is a numeric it contains the dimensions of angle and is proportional to the square root of the magnitude of the unit used for measuring angle. The unit used for the solutions in this paper was the electrical degree. If electrical radians are used, k must be multiplied by the square root of $180/\pi$.)

2. $\dfrac{P_o}{P_m}$ = the initial load ratio.

3. $\dfrac{P_L}{P_m}$ = the abrupt load ratio.

This reduction in the number of coefficients is accomplished by selecting a new variable which is related to the usual time scale by the following equation

$$t = t' \sqrt{\frac{P_j}{P_m}} \tag{7}$$

where t' is the new variable. The substitution of (7) into (6) and the division of all terms by P_m gives the most general form of Equation (6)

$$\frac{d^2\,\theta}{(d\,t')^2} + k\frac{d\,\theta}{d\,t'} + \sin\theta = \frac{P_o}{P_m} + \frac{P_L}{P_m}\ \mathbf{1} \tag{8}$$

This equation characterizes the angular transients that follow a suddenly applied shaft load. It is the equation of a damped pendulum swinging through large amplitudes. Initially, the angle must be of such a value that $\sin\theta_1 = P_o/P_m$. After a transient (in case synchronism is not lost) the final steady-state angle must be such that $\sin\theta_2 = (P_o + P_L)/P_m$.

If k is zero, then the equation represents undamped motion and the angular variation is an oscillation between the initial value and some maximum value. This equation is solvable for the critical load by a method of areas.[2] Also the maximum angle of swing for any load can be determined in the same manner. Should the maximum angle reach and slightly exceed the value of angle corresponding to this critical load in the unstable part of the power-angle characteristic, stability will be lost because the synchronizing torque is less than the load torque. Park and Bancker show a curve of P_o/P_m against P_L/P_m in Fig. 12 of their paper which gives the critical values that are just on the verge of instability. They also show curves of angular position against time for the undamped case which were calculated step-by-step.

The damping is not equal to zero when the induced rotor currents in the field windings and the amortisseur bars are appreciable. The relative damping coefficient k, becomes larger as the induction motor effect becomes greater. By analogy to the damped pendulum, it will be seen that the motion represented by Equation (8) is beneficially influenced by increasing the value of k, since the damping term reduces the maximum angle of swing. In other words, as the value of k becomes larger, the amount of sudden load ratio that may be applied becomes larger with a constant initial load ratio. A limit, however, is reached when k has such a value that the sudden load ratio plus the initial load ratio equals one. Further increase of the relative damping coefficient, k, cannot allow the motor to stand a more sudden load, because the final steady-state conditions are impossible. The value of k that just allows the sudden load ratio plus the initial load ratio to equal one has been termed the "critical damping coefficient." This coefficient has different numerical values for different initial load ratios. It corresponds roughly to the critically damped R, L, and C series electrical circuit.

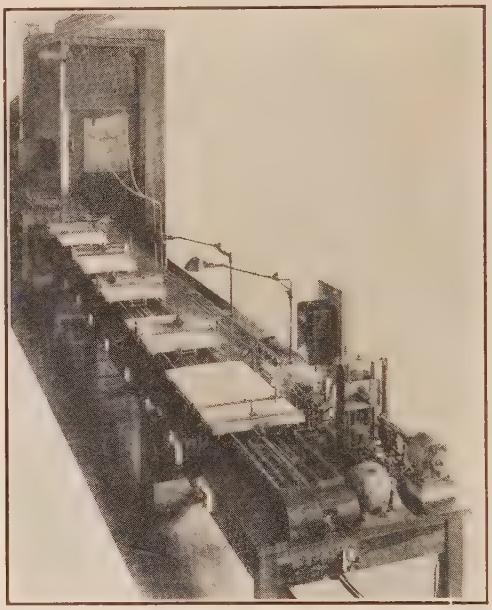


FIG. 1—A GENERAL VIEW OF THE INTEGRAPH

This device is the result of several years of intensive research at the Massachusetts Institute of Technology by Dr. V. Bush and others

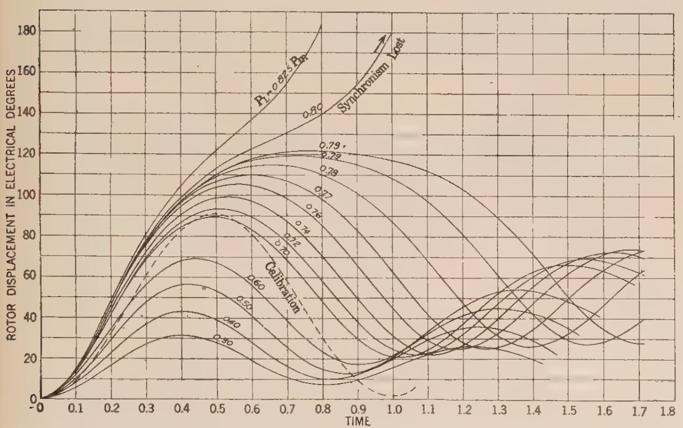
The integraph (see Fig. 1) made it possible for many complete solutions of Equation (8), taking into account the damping term, to be made in a reasonable length of time. Reference to three previously published articles on the integraph describing its construction and operation are given in a footnote below Appendix II. Appendix II describes the methods employed in solving equations of the type of (8) on this device. Without

2. Fortescue, A. I. E. E. TRANS., Vol. 44, 1925, p. 984. Park and Bancker, A. I. E. E. TRANS., Vol. 48, Jan. 1929, p. 170.

2a. Summers and McClure, A. I. E. E., Quarterly TRANS., Vol. 49, 1930, p. 132. (Appendix VIII wherein the Integraph was used for solutions of transient angle-time curves for the undamped case for ten values of initial load ratio and for many sudden load ratios up to 3. Ten charts are given).

the integraph, a tedious point-by-point method would be necessary which would require a prohibitive amount of time.

The procedure used in systematizing the results of the integraph solutions follows. The relative damping coefficient, k, and the initial load ratio, P_o/P_m, were given numerical values. Then the integraph was used to obtain solutions for the angular variation against time for different values of abrupt load ratio, P_L/P_m. Fig. 2 shows such a family of solutions. For these



FOR TIME IN SECONDS MULTIPLY THIS SCALE BY $2\pi \sqrt{\frac{90\,P_j}{P_m}}$

Fig. 2—Curves showing the Variation of Angular Displacement against Time for Various Suddenly Applied Shaft Loads

Angle-time solutions of Equation (8) for a relative damping coefficient of 0.022 and no initial load

solutions, the value of k was equal to 0.022, and P_o/P_m was equal to zero. The time scale is converted to seconds for any particular case by multiplying the numbers on the horizontal scale of Fig. 2 by

$$2\,\pi \sqrt{\frac{90\,P_j}{P_m}} \text{ or } 59.6 \sqrt{\frac{P_j}{P_m}}.$$

The factor $2\,\pi\,\sqrt{90}$ results from the way in which the integraph was calibrated using a linear second degree differential equation without a damping term. This method of calibration is explained in Appendix III.

Small sudden load ratios cause the angle-time solutions of Fig. 2 to resemble damped sinusoids and all have approximately the same frequency. For sudden load ratios larger than 0.4 the frequency of oscillation is considerably reduced, so that for a ratio of 0.79, the time required for one oscillation is doubled.

The integraph solution for the sudden load ratio of 0.80 on Fig. 2 shows there is no oscillation but the angular deviation of the rotor continues to increase and the motor falls out of step. The solution for the ratio of 0.79, however, shows that the angular deviation does reach a maximum value and then oscillates with decreasing amplitude about the final value. Between these values of sudden load ratio there is one for which the angular deviation would neither continue to increase nor decrease. This value is that which would cause the so-called "unstable equilibrium condition" for this particular equation. Physically, such a solution means that the slip and acceleration of the rotor of a synchronous machine both become zero when the rotor reaches the angle giving an unstable steady-state solution. This angle is on the unstable portion of the power-angle curve, thus being greater than 90 deg. The precision of the integraph was not sufficient to secure a plot of this condition. However, the integraph shows that the largest value of sudden load ratio that does not cause instability is greater than 0.79 and less than 0.80. This determination is sufficiently accurate for engineering purposes.

The results of many families of solutions such as those shown in Fig. 2 are compiled as a chart giving the relation between the relative damping coefficient and the maximum load ratio which does not result in instability. Such a chart, complete, in that it gives the results of all the solutions, appears in Fig. 3. The solid points indicate that the integraph solution of Equation (8) with the coordinates of the point k and P_L/P_m is a stable one. The open points indicate that the integraph showed instability for the corresponding values, k and P_L/P_m. Only a few values near the critical value are located on Fig. 3. Between the two types of solutions

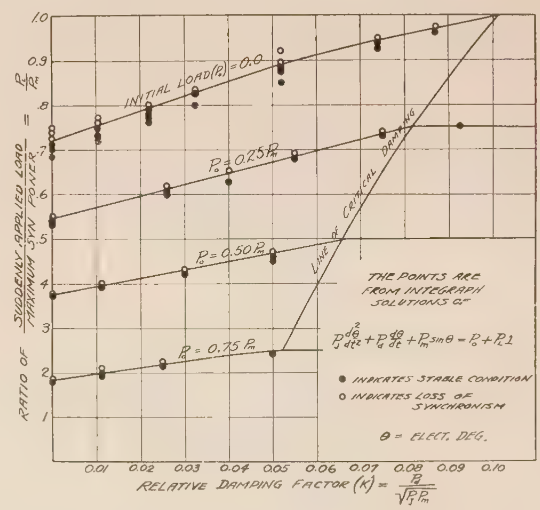


Fig. 3—Charts showing all Possible Solutions of the Type Differential Equation in Terms of Stability

Points for this chart come from solutions similar to those of Fig. 2

there is a boundary line which separates stable and unstable regions.

To get a complete relation between $\frac{P_o}{P_m}$, $\frac{P_L}{P_m}$, and k the following procedure was used. For a particular value of $\frac{P_o}{P_m}$ $\left(\text{say } \frac{P_o}{P_m} = 0\right)$ the critical value of $\frac{P_L}{P_m}$ for a given k was determined by several trial

solutions. This was repeated for several values of k, thus establishing the boundary curve marked "Initial Load, $P_o = 0.0\,P_m$" in Fig. 3. In the same way, the other three boundary curves for initial load ratios of 0.25, 0.50, and 0.75 were located on Fig. 3.

The "line of critical damping" on Fig. 3 is drawn

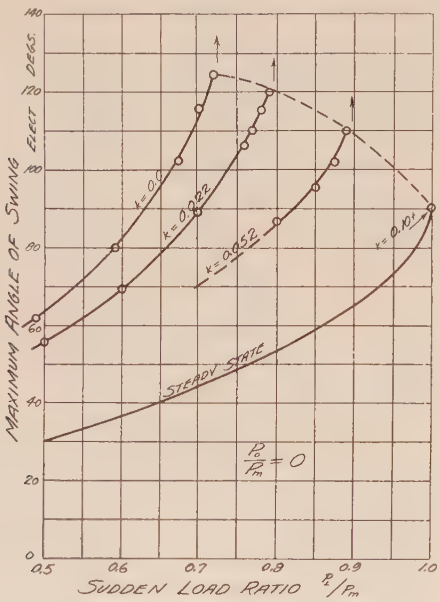


FIG. 4—PLOT OF THE MAXIMUM ANGLE OF SWING FOLLOWING A SUDDEN LOAD

(The arrows indicate that the angle continued to increase, thus showing instability)

through the points where the sum of the initial and sudden load ratios becomes unity. Relative damping factors larger than those for critical damping produce no beneficial effects but only slow up the rate of swing-

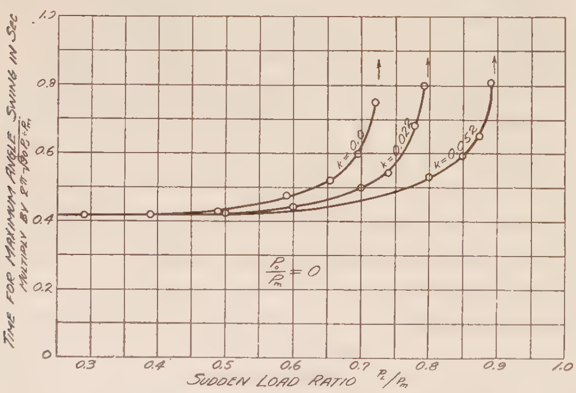


FIG. 5—PLOT OF THE TIME REQUIRED FOR THE ANGLE TO REACH ITS MAXIMUM VALUE IN CASE STABILITY WAS NOT LOST

ing. They do not allow greater loads to be applied without the loss of synchronism.

From the curves similar to Fig. 2, two other charts have been prepared. These are (Fig. 4) the maximum angle of swing plotted against the sudden load ratio for different values of k, and (Fig. 5), the time required for the angle to change to its maximum value as a function of the sudden load ratio for different values of k. The scales of the first curve are independent of the size of the machine, while the second curve has its time scale multiplied by a factor which makes the curves general. Both of the curves are for the case of an initial load ratio of zero.

The time required for one complete swing from the initial angle to the next minimum angle is approximately equal to twice the value of time given in Fig. 5. In other words, the swing back requires the same time as the swing forward.

Many different types of load transient problems are solvable from the results that are plotted in Figs. 2, 3, 4, and 5. These results are in terms of the "relative damping coefficient," k and so easily and quickly apply to the smallest and the largest of synchronous machines. A problem is put into the proper form by finding the

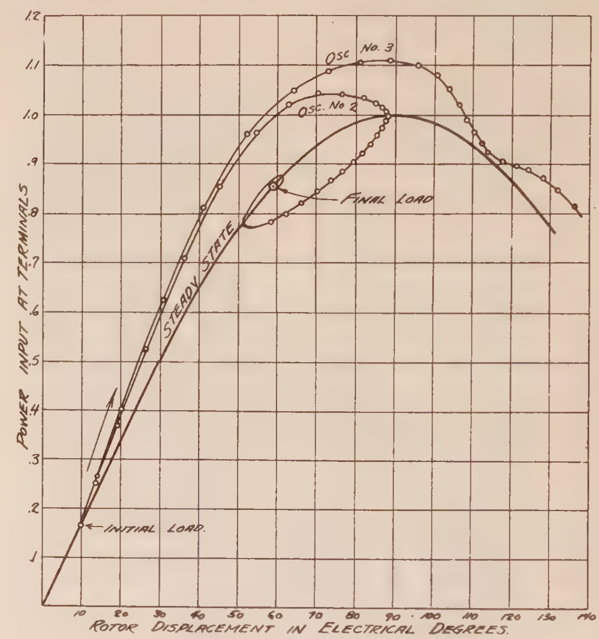


FIG. 6—EXPERIMENTALLY DETERMINED POWER ANGLE DIAGRAM

(For suddenly applied load.)
Steady-state is for gradually applied load

coefficients of the differential equation of torques. Then k is calculated and, together with the initial conditions, allows the desired information to be read from Figs. 2, 3, 4, and 5. Methods of determining the coefficients are given in the complete paper.

ACKNOWLEDGMENT

The authors wish to acknowledge many helpful suggestions during this investigation by members of the Electrical Engineering Staff of the Massachusetts Institute of Technology, especially by Dr. V. Bush, Professors O. G. C. Dahl and M. F. Gardner, and Mr. H. L. Hazen. They also wish to thank Mr. P. L. Alger of the General Electric Company for his helpful advice; Mr. Charles Kingsley, Jr. assisted with the oscillograph work; Messrs. Frank Kear, T. S. Gray, J. B. Russell, Jr., all formerly of the Research Division, aided in making the integraph solutions.

Abridgment of

Traveling Waves on Transmission Lines with Artificial Lightning Surges

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Synopsis.—*The paper describes tests on a transmission line of the Consumers Power Company, using a portable million-volt impulse generator.*

Data were secured on attenuation with one, two, and three conductors in parallel, with and without ground wires. A study was made of the influence of ground wires in reducing voltages induced by overhead discharging clouds, and also the effect on surges of entering or leaving a section of line having ground wires. A brief study was made comparing steel and copper for ground wires. The effect of ground resistance in tower footings was considered and a method given for measuring surge impedance of transmission lines.

In May 1929 the General Electric Company and the Consumers Power Company began a joint investigation of the various effects which take place when overhead circuits are subjected to traveling waves such as those caused by lightning.

The historic S-19 transmission line of the Consumers Power Company between Croton Dam and Grand Rapids,—the first line to transmit electrical energy at 110,000 volts,—was set aside for the study of transients produced artificially. At Croton Dam, an outdoor laboratory housing a cathode ray oscillograph was erected for the purpose of securing records of natural lightning on the T-20 line,[3] and was available for determining the wave form of impulses at the laboratory end of the S-19 line.

The impulse generator used in these tests was a portable million-volt equipment[5] consisting of 40 banks charged in parallel to 25 kv. and discharged in series, as is done in the Marx circuit.[6]

The S-19 line is approximately 45 mi. in length and is not paralleled by any other lines except for a short distance near Grand Rapids. The line does not have a ground wire, nor are the conductorstransposed. Fig. 1 shows a typical tower construction.

Most of the measurements given in this paper were made with sphere gaps which were moved along the line by truck.

Attenuation. In this paper, attenuation will be understood to refer to the decrease in crest surge voltage, without regard to change of wave shape. Corona loss[7] is now generally regarded as the most important factor affecting attenuation. A brief discussion of the more important factors will be given.

Effects of Parallel Conductors. The formation of corona occurs when the potential gradient exceeds the critical value. The gradient is very nearly proportional to the charge on the conductor. At a given potential, the charge is proportional to the electrostatic capacity of the conductor to the earth, which is affected by the presence of other charged conductors nearby, being increased when the other conductors are charged to the opposite sign and decreased when they are changed to the same sign.

When a surge is traveling on a number of conductors in parallel, as is always the case on an actual transmission line, the capacity to earth is reduced by the presence of surges of the same sign on the other conductors. Thus the charge on each conductor at a given surge voltage is less; and so the potential gradient, and

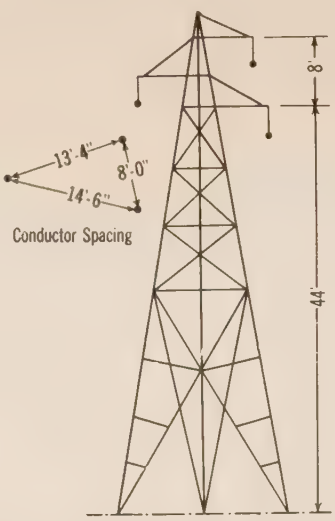

Fig. 1—Typical Three-Post Tower Showing the Arrangement of Conductors

consequently the corona, is less on each conductor than would be the case with a single conductor. Following out this line of reasoning, one would expect to find the attenuation less when several conductors in parallel were carrying the same surge. The tests made show conclusively that increasing the number of conductors in parallel decreases the attenuation.

Effect of Polarity. One would expect that a difference would exist in the corona loss for positive and negative impulses and that in general the loss for the positive impulse would be greater. On this basis, the attenua-

*General Electric Company, Pittsfield, Mass.

†Consumers Power Company, Jackson, Mich.

3. For references see Bibliography.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

tion with negative impulse should be less than for the positive impulse, which was found to be generally true.

Effect of Length of Waves. During the passage of a surge the state of breakdown of the air in the corona area is changing very rapidly. Thus, if the corona loss was greatest during the initial stages of breakdown, a short wave would suffer more attenuation than a long wave.[10]

Effect of Ground Wire. With a traveling wave, the ground wire takes up a charge opposite in sign to that of the wave in the line conductor, and as previously pointed out, this results in an increased charge on the

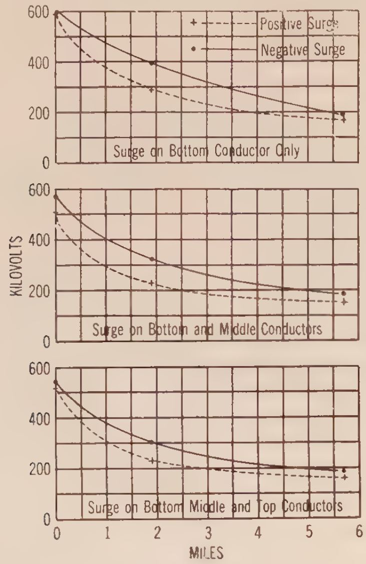

FIG. 2—ATTENUATION WITH STEEP WAVES ON ONE, TWO, AND THREE CONDUCTORS

line conductors which results in an increased corona loss at a given potential. This effect is conducive to increase of attenuation. On the other hand, the increase in charge results in an increase in the energy of the surge, which tends to decrease the attenuation. Previously it has been assumed[11] that the resultant effect of the ground wire is to increase the attenuation, but the attenuation was found to be less with the ground wire, especially in the case of the negative impulse on the line conductor. Apparently, in the case of the positive impulse the increase in surge energy and corona loss are more or less balanced, but with the negative surge, the increase in surge energy seems to be greater than the increase in corona loss, resulting in a decreased attenuation.

Test Results. The attenuation tests were made, using three different wave forms,—a fast wave, reaching its crest in less than one microsecond; a slow wave, reaching its crest in seven microseconds; and a chopped wave, produced by cutting off the slow wave at its crest by the use of a parallel sphere-gap. The influence of the ground wire on attenuation was studied by grounding the conductors at approximately one-half mile intervals.

In Fig. 2 are given curves showing the variation in measured crest voltage with distance for both positive and negative steep waves. The applied voltage decreases with the number of conductors in parallel because of the increased load on the surge generator. The positive wave in each case shows more attenuation for potentials in excess of 200 kv. than does the negative.

The attenuation tests with the slow wave extended over a distance of 30 mi. from the impulse generator. A formula derived by Foust and Menger[7] fits the data fairly well for the first 10 miles, beyond which the loss due to corona becomes small.

It is of interest to note that on the Turners Falls Line,[1] a brief study of attenuation on a single conductor gave for n and k values quite different from those obtained on the S-19 line, and indicate that the values of n and k must be determined for each individual condition considered.

The results of the tests made with the chopped slow wave are given in Fig. 3.

It is to be noted that the potential of the free wire and of conductors carrying the surge have all come to the same value in a distance of 5.7 mi. The attenuation is greater with a single conductor than with simultaneous surges on multiple conductors, although this effect is much more pronounced with the chopped wave than with the others. This may be due to the transference of a large percentage of the wave energy to the free conductors in the case of the chopped wave.

Considerable work was done in the study of attenuation with ground wires, the results shown in Fig. 4 being representative of the results obtained.

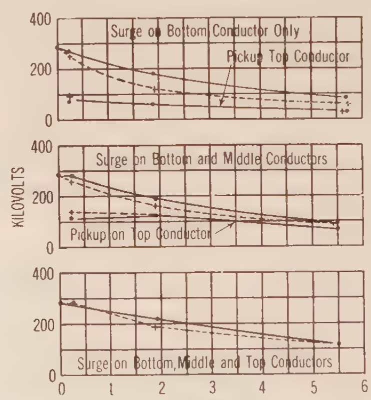

FIG. 3—ATTENUATION WITH CHOPPED SLOW WAVES ON ONE, TWO, AND THREE CONDUCTORS

The impulse was always applied to the bottom conductor at Tower C. Tests were made with both positive and negative impulses. In comparing these tests, it should be remembered that the top and middle conductors are 8 ft. and 14 ft., respectively, from the bottom conductor, which means that the top conductor acting as a ground wire will influence the bottom conductor more than the middle wire will when it is grounded.

These results indicate that for positive impulses the ground wires have but little effect on the attenuation. In the case of negative impulses it appears that the

presence of one ground wire so decreases the attenuation that the impulse may travel twice as far with the ground wire as without it. Two ground wires increase this effect slightly. The idea that ground wires should damp out traveling waves quickly does not seem to hold; in fact the tests show that the reverse is true. This does not mean that ground wires are not useful in reducing the potential which would otherwise have been present when the line is under a discharging cloud, nor does it mean that the ground wire would not be helpful in case of a direct stroke of lightning to the ground wire or line wires.

These tests indicate that the ground wire acts most efficiently when the storm is close to the point considered, as will always be the case with line insulators or when storms are close to station apparatus.

Study of Ground Wires. When a cloud over a transmission line becomes charged, all of the conductors of the transmission line including the ground wires take up charges having a polarity opposite to that of the cloud.

When the lightning discharge takes place, the charges on the ground wires are free to pass directly to the earth, while the charges on the line conductors travel

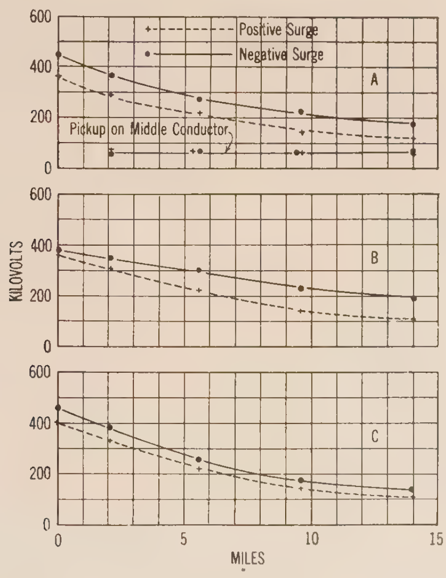

Fig. 4—Attenuation on Line Under Influence of Ground Wires

into other portions of the system as traveling waves. It is the function of the ground wires to reduce the potential appearing on the line conductors just after the lightning discharge takes place but before the charges begin to travel along the line wires. The mechanism of this reduction is frequently divided into two parts, which will be referred to as the first and second actions of the ground wire.

It is assumed that the charge on the ground wire runs off to earth in zero time, so that because of the elimination of the charge on the ground wire, the line conductors find themselves with an increased capacity but with the same charge that they had with the original capacity. As the product of the potential and the capacity is equal to the charge which is constant, an increase in capacity results in a decrease in potential, which constitutes the *first effect* of the ground wire.

The *second effect*, which is smaller in magnitude than the first, results from a further increase in capacity of the line conductors as the ground wires take up charges of the opposite sign, due to the field of the line conductors to ground. It is interesting to note that the sum of the first and second charges on one or more ground wires is just equal to the charges they would

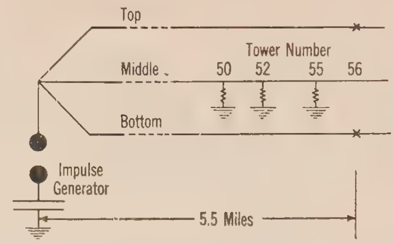

Fig. 5—Set-Up for Study of First Ground Wire Effect

have had if no other conductors were present. For purposes of calculation, the first and second effects of the ground wire are conveniently considered together, and in the tests to be described, the effects were studied together, but the second effect was also studied separately.

A fair measure of the effect on the potential of the line conductors,—that of changing the charge on the ground wire—may be obtained by the use of traveling waves although the ground wire theory is predicated on static conditions. As previously pointed out, the potential of any one conductor is affected by charges on the parallel conductors; and this is true whether the charges are moving or stationary.

In making the tests to show the total effect, the three conductors were connected as shown in Fig. 5. Voltages were all measured at Tower 56.

The surge applied had a front of about 10 microseconds. The results obtained are given in Table I,

TABLE I
TOTAL GROUND WIRE EFFECT

Tower at which middle conductor was grounded*	Voltages measured kv. at tower 56			Protective factor	
	Top	Middle	Bottom	Top	Bottom
No grounds	178	168	177	100%	100%
50	..	40	146	..	83.5
50, 52	..	34	145	..	83.0
50, 52, 55	143	4.3	142	80.6	80.0

*The ground resistances were—Tower 50, 76.4 ohms; Tower 52, 28.4 ohms; Tower 55, 7.5 ohms.

and show the protective value of the ground wire, which is the same for both positive and negative impulses.

The calculated protective factors for the total effect assuming the middle conductor at earth potential are 79

per cent and 77 per cent for the top and bottom conductor, respectively.

It is interesting to note that the greatest reduction of potential occurred at the first tower, although the tower resistance was 76.4 ohms. This indicates that a large part of the benefit of the ground wire, for reduction of induced discharges, will be retained with tower footing resistance of the order of 75 ohms.

Copper vs. Steel Ground Wire. A limited number of tests was made in an effort to determine the relative merits of copper and steel conductors acting as ground wires. The tests made, which relate only to traveling wave effects at comparatively low voltages, do not show any marked difference between copper and steel ground wires.

Effect of Ground Resistance. Measurements of tower footing resistance were made with a megger constructed especially for this purpose. The resistances were found to vary from 12 to more than 1500 ohms.

To measure a ground resistance under impulse conditions, sphere-gap measurements were made. In every case the transient resistance was less than that measured under steady state conditions, which is in agreement with cathode ray oscillograph tests made at Pittsfield.[12] One such test shows that the ground resistance with a transient current of 550 amperes is about 67 per cent of the steady state resistance. Tests indicate that two grounds of, for example, 50 ohms each are better if separated some distance apart than one ground of half the resistance in one location. This seems to indicate the desirability of keeping the ground resistance of towers uniformly as low as possible, rather than having wide variations in tower footing resistance, even though some are low but with a high average.

Measurement of Surge Impedance. Some difficulty has been experienced in measuring the surge impedance of the transmission line conductors. The method finally adopted was to connect a variable resistance between line and ground at a point sufficiently remote from the generator to be sure that traveling wave conditions were established, and plot a curve between amperes through the resistance and the potential to ground. If the measurement is not made at the end of a line, the voltage at zero current is to be divided by one-half of the current at zero volts, which will give the surge impedance. If the measurement is made at the end of a line remote from the generator, the voltage at zero current divided by the current at zero voltage will give the surge impedance.

Conclusions. A million-volt impulse generator of sufficient capacity for field use with limited power facilities available, has been shown to be satisfactory in use, and still higher potentials can be obtained when necessary.

The tests have shown the following:

1. Surges attenuate less rapidly when other nearby parallel conductors are carrying similar surges.

2. In general, positive surges attenuate more rapidly than do negative surges although in some tests but little difference was found.

3. Short waves, such as a wave chopped on the front by an insulator flashover, attenuate more rapidly than do longer waves of the same crest value.

4. An additional constant has been introduced into the formula for attenuation, which seems to give better agreement with the test results.

5. The presence of the ground wire reduces the attenuation considerably for the negative wave and to a lesser degree for the positive impulse.

6. The ground wire theory of reduction of induced potentials was checked using traveling waves. The results agree with the protective ratio for the ground wire given by the usual calculation. For the conductor arrangement used, the calculated reduction was 21 and 23 per cent, while the test showed 20 per cent reduction for the total ground wire effect.

7. The second ground wire effect was checked also with traveling waves and it was found that when entering or leaving a section with one or two ground wires, the surge voltage was decreased or increased 8 per cent respectively. These approximate the calculated value based on the change in surge impedance. These results indicate that very little is to be gained by putting up additional ground wires near a station to reduce an incoming impulse. From the standpoint of additional protection from lightning discharges which originate close to the station, their use may be justified.

8. The test indicates that there is little difference between steel and copper conductors from the standpoint of their ability to transmit impulses.

9. If but two grounds of equal value are to be used, the greatest reduction in wave transmitted beyond the resistances occurs when the resistances are at least half a wavelength apart. Thus, two resistances of 40 ohms a half-mile apart will more effectively ground the line than one resistance of 20 ohms. This seems to indicate that uniform low resistance is preferable to widely varying resistances.

10. Transient ground resistance is less than the resistance measured under steady state conditions.

11. The surge impedance of a transmission line may be satisfactorily determined from a series of voltage and current readings with varying values of resistance between line and ground.

The authors wish to express their appreciation to the officials of both the Consumers Power Company and the General Electric Company who have made this joint investigation possible. Much credit is due to Messrs. Rudge, Brune, Eaton, Wade, and others who were responsible for conducting the tests in the field, and to Messrs. Boehne, Brinton, and Brownlee who also assisted in the preparation of the paper.

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A Proof that the Induction Motor Circle Diagram

Applies to the Transmission Line

BY F. CREEDY[1]

Member, A. I. E. E.

Synopsis.—*The paper shows that the well-known circle diagram, first developed for the induction motor, is in reality applicable to the general network, however complicated, and therefore to the transmission line. The double-frequency power diagram is criticised as needlessly complicated, and the well-known constructions applied to all quantities of interest in the transmission line. Since it occupies only a few lines, elementary proofs are given of those parts of general circuit theory needed.*

THE equations for the general circuit, in terms of the so-called "general circuit constants," are usually given in the form below, where E_s, I_s are sending end voltage and current, and E_r, I_r corresponding quantities at the receiving end:

$$E_s = A\,E_r + B\,I_r\,. \quad (1) \qquad E_r = D\,E_s - B\,I_s \quad (3)$$

$$I_s = C\,E_r + D\,I_r\,. \quad (2) \qquad I_r = -\,C\,E_s + A\,I_s \quad (4)$$

No further proof of the equations (1) and (2) is necessary than to note that in the elementary circuit, $E = I\,Z$, a linear relation, and current and voltage for the general circuit are found by summations according to Kirchhoff's laws. No summations can change a linear relation to one of higher order. Furthermore, when $E = 0$, $I = 0$, so that no constant term can appear. We are therefore entitled at once to write the relation between E_s, I_s and E_r, I_r in the most general linear form not containing constant terms, as has been done above. Equations (3) and (4) result from solving (1) and (2) for E_r, I_r, and putting $A\,D - B\,C = 1$ a relation proved below.

EQUIVALENT CIRCUITS

No matter how complex the circuit to which the Equations (1) and (2) apply, we may represent it fully by an equivalent circuit containing not more than four independent parameters (impedances) such that by assigning them suitable values, any values whatsoever of A, B, C, D can be obtained.

Such a circuit is shown in Fig. 1.

Working out the equations for this circuit, we obtain,

$$E_s = E_r\,[1 + Y_4\,Z_5 + Z_o\,(Y_3 + Y_4 + Y_3\,Y_4\,Y_5)] + I_r\,[Z_5 + Z_o\,(1 + Y_3\,Z_5)]$$

$$I_s = E_r\,[Y_3 + Y_4 + Y_3\,Y_4\,Y_5] + I_r\,[1 + Y_3\,Z_5]$$

This gives clearly four simultaneous equations to determine A, B, C, D in terms of the four independent parameters Z_o, Z_5, Y_3, Y_4. Thus, these equations can always be satisfied by suitable values of the latter. On multiplying out the coefficients of $E_r\,I_r$ in these equations, it is easy to prove that $A\,D - B\,C = 1$ for

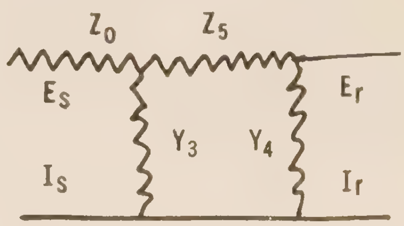

FIG. 1

this case. This is true for any values whatever of the parameters. Hence it is true generally for any values of A, B, C, D, since any such values can be constructed by suitable values of the parameters. This supplies a proof of this relation from first principles.

Having proved this relation, which shows that only three of the four constants A, B, C, and D are independent, simpler circuits may be used; for instance, we may put $Z_o = 0$ in Fig. 1 (the so-called π circuit); or again, Equations (1) and (2) may be written[2]

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2. R. D. Evans, A. I. E. E. TRANS., 1926, p. 81.

$$E_o = \frac{E_s}{A} = E_r + I_r \frac{B}{A} = E_r + I_r Z$$

$I_o = A I_s = E_r A C + I_r A D = Y E_r + (1 + Y Z) I_r$ in terms of the circuit in Fig. 2, in which A represents a transformation, the voltage E_s being reduced in the ratio of $\frac{1}{A}$ and the current increased in the same ratio, while a certain phase shift is also produced (A a complex

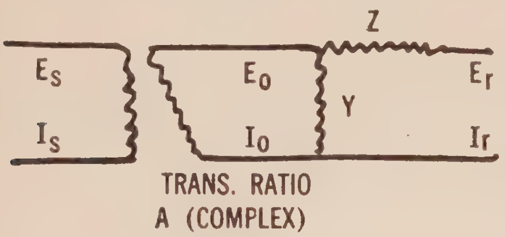

Fig. 2

number). Such a circuit contains three independent parameters and hence may also represent the general equations. It is the so-called T circuit and is included here because of its close analogy to the divided circuit used to represent the induction motor. In what

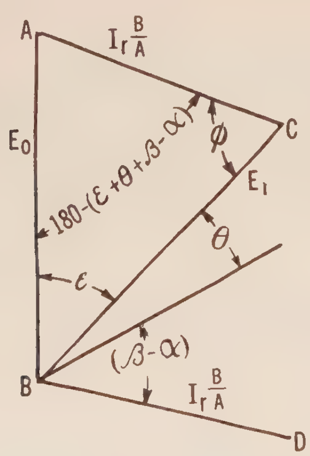

Fig. 3

follows, however, the circle diagram will be derived direct from the general equations.

To obtain the diagram, it is necessary only to understand these equations clearly.

Equation (1) states that the three vectors shown form a triangle as in Fig. 3, where $A\,B = E_o$, $B\,C = E_r$, and $A\,C = B\,D = I_r \frac{B}{A}$. Now assume further that the receiver end takes power *at constant power factor,* the phase difference between E_r and I_r being θ a constant.

Adopting the polar form for the complex numbers, let

$$A = a \angle \alpha = 187 \angle 5 \text{ deg.}$$
$$B = b \angle \beta = 197 \angle 80 \text{ deg.}$$
$$E_r = e_r \angle \epsilon$$
$$I_r = i_r \angle \epsilon + \theta$$
$$E_o = e_o \angle 0 = 100 \text{ kv.}$$
$$\frac{B}{A} = \frac{b}{a} \angle \beta - \alpha$$
$$\frac{I_r B}{A} = i_r \frac{b}{a} \angle \epsilon + \theta + (\beta - \alpha)$$

As will be seen from the angles marked on the diagram, (Fig. 3,) $B\,D$ makes an angle $\epsilon + \theta + (\beta - \alpha)$ with $A\,B$ so that the angle $B\,A\,C = 180 - (\epsilon + \theta + (\beta - \alpha)$. The angle $A\,B\,C$ is ϵ and the angle $A\,C\,B$ is called ϕ. Hence:

$$180 - (\epsilon + \theta + \beta - \alpha) + \epsilon + \phi = 180 \text{ deg.}$$
$$\phi - (\theta + (\beta - \alpha)\,) = 0$$

Thus the angle $\phi = \theta + (\beta - \alpha)$ is constant if $\theta =$ constant and the point C moves on a circle.

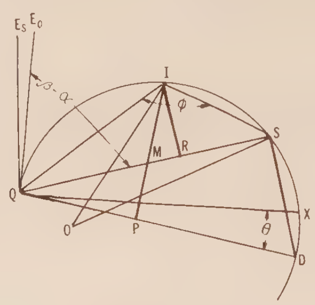

Fig. 4

To give $\phi = 90$ deg., $\theta = 90 - \beta + \alpha$ would be necessary.

Dividing by $\frac{B}{A}$ we simply turn the diagram through an angle $(\beta - \alpha)$ and alter its scale. The side $A\,C$ which before represented $\frac{I_r B}{A}$ now represents I_r.

This has been done in Fig. 4, where $Q\,I$ corresponds to $A\,C$. $Q\,S$ to $A\,B$ and I_s to $C\,B$.

Draw $Q\,S = \frac{E_o A}{B}$ the short-circuit current, so that the angle $E\,Q\,S = (\beta - \alpha)$. Draw a triangle $S\,I\,Q$ such that the angle $S\,I\,Q$ is $(\theta + \beta - \alpha)$ and a circle passing through S, I, and Q.

From I, drop a perpendicular $I\,R$ on $Q\,S$ and draw a line $I\,M$ such that the angle $Q\,M\,I = Q\,I\,S$. Draw a line $Q\,D$ at right angles to $I\,M$ to cut $I\,M$ produced in P, and to cut the circle in D. Join $D\,S$. Since $I\,R$ is perpendicular to $Q\,S$ and $I\,M$ to $Q\,D$, the angle

$M\,I\,R = S\,Q\,D$. The angles $I\,M\,R + I\,M\,Q = Q\,I\,S + Q\,D\,S = 180$ deg. and since $Q\,M\,I = Q\,I\,S$, the angle $I\,M\,R = Q\,D\,S$. Hence the triangles $I\,M\,R$ and $Q\,S\,D$ are similar and since $I\,M\,R$ is a right angle $Q\,S\,D$ is also a right angle. Hence $Q\,D$ is a diameter.

Now the angles

$$I\,M\,R = M\,I\,R + I\,R\,M = 180 \text{ deg.}$$
$$I\,M\,R = 180 - Q\,I\,S \quad I\,R\,M = 90 \text{ deg.}$$
$$(180 - Q\,I\,S) + 90 \text{ deg.} + M\,I\,R = 180 \text{ deg.}$$
$$M\,I\,R = Q\,I\,S - 90 \text{ deg.}$$
$$M\,I\,R = (\theta + \beta - \alpha) - 90 \text{ deg.}$$
$$(\beta - \alpha) - 90 = S\,Q\,X$$
$$\theta = X\,Q\,D.$$

Thus a circle through S and Q whose center lies on the line $Q\,D$ which is drawn as stated is the locus of the current vector I_r for any fixed value of θ which is the angle between E_r and I_r.

In most cases α is practically zero. It has been exaggerated in the figure to enable us to study its influence. Draw $O\,V = E_o \underline{/2\,\alpha}$ making an angle $2\,\alpha$ with $O\,E_o$ and of the same magnitude. Turning to the third equation, we have

$$E_r = D\,E_s - B\,I_s = A\,D\,E_o - \frac{B}{A}\,I_o$$

$$E_r \frac{A}{B} + I_o = \frac{D\,A^2}{B}\,E_o$$

From the point S already obtained Fig. 4, set off

$S\,O = \dfrac{D\,A^2}{B}\,E_o = \dfrac{D\,A\,E_s}{B}$. Since $S\,I = E_r \dfrac{A}{B}$ as shown above, we have $O\,I = I_o$. Therefore $O\,I$ to a suitable scale (depending on the open-circuit voltage transformer ratio A) measures the sending end current and its projection on $O\,V$, the watt input, since $\overline{I_s A} \times \dfrac{E_s}{A} = \bar{I}_s\,E_s \dfrac{\bar{A}}{A}$. Now $Q\;I\;.\;I\;S \sin\phi$

$= 2 \times$ area of triangle $Q\,I\,S = Q\,S\;I\,R$

But $I\,R = I\,M \sin\phi$, therefore

$$Q\,I\,.\,I\,S \sin\phi = Q\,S\,.\,I\,M \sin\phi$$
$$Q\,I\,.\,I\,S = Q\,S\,.\,I\,M$$

But $Q\,I = I_r$ and $I\;S = e_r \dfrac{a}{b}$ so that $Q\;I.\;I\;S$ is proportional to the volt-amperes at the receiving end. Since $Q\,S$ is constant, therefore $I\;M$ is proportional to the volt-amperes received.

Now the angle between I_r and E_r is θ and the angle between $I\,M$ and $O\,E_o$ is θ. Consequently the projection of $I\,M$ on $O\,E_o$ is the true watts output of the line. If $\theta = O$, $I\,M$ will be parallel to $O\,E_o$.

Fig. 5 gives the full diagram including constructions for all quantities of interest and means of determining the scales. It has been drawn for unity power factor, and the dotted circles represent the case of leading and lagging power at the receiving end. It should be noted that the diagram is *not* a double-frequency power diagram (which the writer believes to be of doubtful utility) but a diagram of current and e. m. f. of the familiar type. It is absolutely general and applicable to all circuits whatsoever. Applied to a simple circuit of constant inductance "loaded" with resistance loads of varied amounts, we reproduce the diagram of the elementary textbooks. Applied to the induction motor circuit, we obtain the equally well-known diagram. In Fig. 5, for greater clearness, the origin has been transferred to the point O. Therefore the operation of the line is as follows:—On open circuit, (receiver end), the equivalent sending end current is $O\,Q$ leading because of the proponderating capacitance of the line under these conditions. As the receiver load increases, the sending end current travels round the circle till it reaches the topmost point when the line stability suddenly "breaks down" just as in the induction motor, and the voltage falls to zero. One advantage of this diagram is that the "breakdown point" is obtained directly without need for a point-by-point construction as with the double frequency diagram.[3]

Another important point is to note that the diagram is completely determined if we know $O\,Q$ and $O\,S$ or $O\,Q$ and $Q\,S$. $O\,Q$ is the equivalent open-circuit sending end current (taken with correct phase involving a knowledge of open-circuit watts). $O\,S$ is the equivalent short-circuit sending end current (with correct phase).

The Circle Coefficient of the General Circuit

We may here introduce a further conception.

Let $\sigma = \dfrac{I_{so}\,A}{I_{sc}\,A} = \dfrac{O\,Q}{O\,S}$ be called the circle coefficient of the general circuit. (A complex number).

$$\sigma = \frac{C\,E_s}{\dfrac{A\,D\,E_s}{B}} = \frac{B\;C}{A\;D} = 1 - \frac{1}{A\;D}\,^*$$

Further relations are

$$I_{sc} = \frac{I_{so}}{\sigma} = \frac{C\,E_s}{\sigma} \quad \text{Also B. C.} = \frac{\sigma}{\sigma - 1} \quad \text{A. D.} = \frac{1}{1 - \sigma}$$

$$I_{sc} - I_{so} = I_{rs} \text{ or } I_{so}\frac{1 - \sigma}{\sigma} = I_{rs}$$

3. The proportions of the diagram are chosen nearly to suit the constants given by Miss Clarke, A. I. E. E. Trans., 1926, p. 30. On 220 kv., the maximum capacity works out to 102,000 kw. against her 106,000. The difference is due to the angle α being here taken somewhat larger so as to show on the diagram.

*Note analogy to $= 1 - \dfrac{1}{v\,v_1}$ where v, v_1, are primary and secondary leakage factors.

or $OS - OQ = QS$ (Fig. 5.)

or $\frac{A D E_s}{B} - C E_s = \frac{E_s}{B}$.

and in fact the whole theory of σ may be transferred bodily to the general circuit. Interesting results may be obtained by considering σ as a function of $p = \frac{d}{d t}$.

This constant σ is a quantity independent of the voltage or kv-a. capacity which completely differentiates between a line of intrinsically good or bad regulation. To draw the regulation curves we require in addition the open-circuit admittance which will (other things equal) be proportional to the kv-a. capacity and the voltage at which it operates. But σ measures its inherent good or bad regulating qualities apart from size and voltage. The smaller σ can be made the better the regulation.

It is clear that the "overload capacity"—(it is convenient to transfer the familiar terms to the general circuit so long as we are using the familiar diagram),—is enormously increased if the receiver power leads, and this is the justification for the use of a synchronous condenser at the receiving end. But a slight examination of the diagram shows that if QS or OS is small (o large) the use of a synchronous condenser to procure stability on heavy load might mean that E_r on full load must be considerably greater than on no-load together with other inconveniences such as considerable phase displacements. Hence in the general circuit it is just as important as in the induction motor that σ should be small which means, in effect, that the short-circuit current should be large. The use of a synchronous condenser means correcting an unsatisfactory condition after it has occurred while keeping σ small means avoiding its occurrence.

The next point to consider therefore is how σ may be minimized. In the first place it will be clear that in the transmission line the fundamental phenomena will be unchanged if we neglect the losses σ then becoming a scalar.

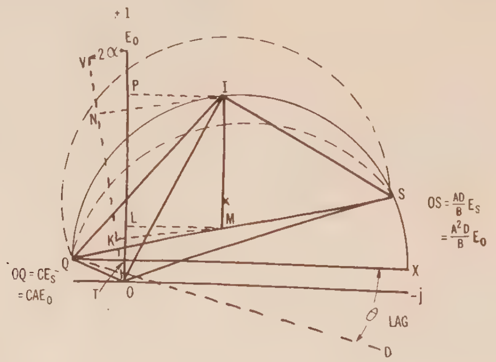

FIG. 5

All vectors correct phase relative to E_0 unless otherwise stated

$I O$	= Sending end volt-amperes. (Scale D)	$I O$	= Sending end current. (Scale C)
$I M$	= Receiving end volt-amperes. (Scale D)	$T K$	= Load loss. (Scale D)
$N O$	= Sending end watts. (Scale D)	$T O$	= No-load loss. (Scale D)
$P L$	= Receiving end watts. (Scale D)	$O Q$	= No-load sending end current. (Scale C)
$P L/N O$	= Line efficiency. (Scale D)	$O S$	= Short-circuit sending end current. (Scale C)
$O I$	= Receiver current. (Scale A)	$Q S$	= Short-circuit receiving end current. (Scale A)
$I S$	= Receiver volts (not correct phase). Scale B		
$I S/Q S$	= Receiving/sending end volts		

SCALES

Let $E_s = 100$ kv. $b = 197$ $a = 87$

Scale A (arbitrary) say 50 amperes per cm.

Scale B $= \frac{50 \times b}{a} = 11{,}300$ volts per cm.

Scale C $= \frac{50}{a} = 57.7$ amperes per cm.

Scale D $= \frac{50 \times E_s}{a} = 5770$ kv-a. per cm.

NOTES

$O T$ to be measured along $O V$

Multiply by $\sqrt{3}$ to get three-phase values

Procedure: From O set off $O Q = C E_s$ and $O S = \frac{A D}{B} E_s$. Through Q draw $Q X$ parallel to the j axis. From Q draw $Q D$ making an angle with $Q X$. Draw a circle through Q and S having its center on $Q D$. If $\theta = 0$, $Q D = Q X$.

In this case

$$A = D = \cos (l p \sqrt{L C})$$

L = coeffi. of self ind. per unit length

$$B = \sqrt{\frac{L}{C}}\, j \sin (l p \sqrt{L C})$$

C = Cap. per unit length

$$C = \sqrt{\frac{C}{L}}\, j \sin (l p \sqrt{L C})$$

l = length $p = 2 \pi \times$ frequency.

$$\sigma = -\frac{\sin^2 (l\,p\,\sqrt{L\,C})}{\cos^2 (l\,p\,\sqrt{L\,C})} = -\tan^2 (l\,p\,\sqrt{L\,C}).$$

σ is negative because $O\,Q$ and $O\,S$ are in opposite directions.

For small values of $\sin l\,p\,\sqrt{L\,C}$ we may put $\sin l\,p\,\sqrt{L\,C} = l\,p\,\sqrt{L\,C}$ and $\cos l\,p\,\sqrt{L\,C} = 1$, giving

$$O\,S = \frac{C\,E_s}{\sigma} = \frac{j\,l\,p\,c}{-l^2 p^2 C\,L} = \frac{E_s}{j\,L\,p}$$ showing the preponderating importance of self induction.

In general σ may be reduced by (1) reducing frequency; (2) reducing length; and (3) reducing L or C. (This latter does not increase short-circuit current and is therefore unavailable).

Abridgment of

Transoceanic Telephone Service—Short-Wave Transmission

Transmission Features of Short-Wave Radio Circuits

BY RALPH BOWN[1]

Non-Member

***Synopsis.**—The discussion relates to the transmission problems involved in short-wave radiotelephony over long distances, and the transmission bases for design of the systems used in commercial transatlantic service. Choice of operating frequencies, amounts of transmitter power, directive transmitting and receiving antennas, automatic gain controls in receivers, and voice-operated switching devices are all factors which may be invoked to aid in solving these problems. The way in which they have been applied in the transatlantic systems and the results which have been obtained are set forth briefly.*

TRUNK circuits which furnish telephone service between London and New York, and also permit successful conversation by means of toll wire extensions between the United States and Europe more generally, are being carried over both long waves and short waves. It is the purpose of this paper to consider the transmission side of the new short-wave circuits which the American Telephone and Telegraph Company and the British General Post Office have made available for this service.

The frequency range so far developed for commercial radio use is roughly 20 to 30 million cycles wide, extending from about 10 kilocycles to perhaps 25,000 kilocycles per second. There are two parts of this whole spectrum suitable for transoceanic radiotelephony—the long-wave range, which is relatively narrow, extending roughly from 40 kilocycles to 100 kilocycles, and the short-wave range, which in its entirety is much broader, extending from about 6000 kilocycles to 25,000 kilocycles.

The short-wave range is very wide in kilocycles but nevertheless has its limitations as to the number of communication facilities it affords. For a given route of a few thousand miles, a single frequency gives good transmission for only a part of the day. For example, from the United States to Europe, a frequency of about 18,000 to 21,000 kilocycles (17 to 14 meters) is good during daylight on the Atlantic; but in the dawn and dusk period, a frequency of about 14,000 kilocycles (22 meters) is better. For the dark hours, something like 9000 kilocycles (33 meters) gives best transmission, and for midnight in winter, an even lower frequency near 6000 kilocycles (50 meters) is advantageous. Thus, in considering the short-wave range in terms of communication circuits, we must shrink its apparent width materially to take account of the several frequencies required for continuous service.

Interconnecting with Wire Circuit Extensions

In its essentials, the skeleton of a radiotelephone circuit is very simple. It consists merely of a transmitter and a receiver at each end of the route and two oppositely-directed, one-way radio channels between them. These two independent channels must be arranged at the terminals to connect with two-wire telephone circuits in which messages in opposite directions travel on the same wire path. The familiar hybrid coil arrangement, so common in telephone repeaters and four-wire cable circuits, might appear to solve this problem were there not difficulties peculiar to the radio channels. In the short-wave case, within short intervals of time, large variations in attenuation occur in the radio paths. These would tend to cause re-transmission of received signals at such amplitudes that severe echoes, and even singing around the two ends of the circuit, would occur unless means were provided to prevent this.

1. Department of Development and Research, American Telephone and Telegraph Company, New York, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

2. For detailed description of this system see "The New York-London Telephone Circuit" by S. B. Wright and H. C. Silent *Bell, System Tech. Jl.*, Vol. VI, October, 1927, pp. 736-749.

To overcome these fundamental transmission difficulties, an automatic system of switches operated by the voice currents of the speakers has been developed.[2] These devices cut off the radio path in one direction while speech is traveling in the reverse direction, and also keep one direction blocked when no speech is being transmitted. The operation is so rapid that it is unnoticed by the telephone users. Since this system prevents the existence of singing and echo paths, it permits the amplification to be varied at several points almost without regard to changes in other parts of the system, and by manual adjustment it is possible to maintain the volumes passing into the radio link at relatively constant values, irrespective of the lengths of the connected wire circuits and the talking habits of the subscribers.

Fig. 1 gives a schematic diagram of the United States end of one of the short-wave circuits, showing the essential features of a voice-operated device which has been used. This kind of apparatus is capable of taking many forms and is of course subject to change as improvements are developed. The diagram illustrates how one of these forms might be set up. This form

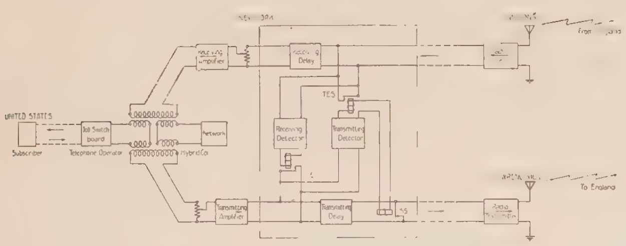

Fig. 1—Circuit Diagram Illustrating Operation of Voice-Operated Switching Device

employs electromechanical relays. The functioning of the apparatus illustrated is briefly as follows: the relay TES is normally open so that received singals pass through to the subscriber. The relay SS is normally closed to short-circuit the transmitting line. When the United States subscriber speaks, his voice currents go into both the transmitting detector and the transmitting delay circuit. The transmitting detector is a device which amplifies and rectifies the voice currents to produce currents suitable for operating the relays TES and SS, which thereupon short-circuit the receiving line and clear the short circuit from the transmitting line, respectively. The delay circuit is an artificial line through which the voice currents require a few hundredths of a second to pass, so that when they emerge, the path ahead of them has been cleared by the relay SS. When the subscriber has ceased speaking, the relays drop back to normal.

The function of the receiving delay circuit, the receiving detector, and the relay RES, is to protect the transmitting detector and relays against operation by echoes of received speech currents. During irregularities such echoes arise in the two-wire portion of the connection and are reflected back to the input of the transmitting detector, where they are blocked by the relay RES which has closed and which hangs on for a brief interval to allow for echoes which may be considerably delayed. The gain control potentiometers, shown just preceding the transmitting and receiving amplifiers, are provided for the purpose of adjusting the amplification applied to outgoing and incoming signals.

The relief from severe requirements on stability of radio transmission, and from varying speech load on the radio transmitters which this system provides, permits much greater freedom in the design of the two radio channels than would otherwise be possible.

The Radio Channels

One of the first questions which come up in considering the design of a radio system is the power which can be sent out by the transmitter. The word "can" is used advisedly, rather than "should," since, in the present art, the desideratum usually is the greatest amount of power that is technically possible and economically justifiable. There are few radio systems so dependable that increased power would not improve transmission results. At very high frequencies, the generation of large powers is attended by many technical difficulties, but fortunately the radiation of power can be carried out with much greater efficiency than is feasible at lower frequencies. At 18,000 kilocycles (about 16 meters) a single half-wave radiator, or doublet, is only about 25 ft. long, and it is possible to combine a number of them, driven in phase by a common transmitter, into an antenna array which concentrates the radiated power in one geographical sector. In that direction, the effectiveness may be intensified 50 fold or more, (17 db.), and waste radiation in other directions reduced materially. Thus, one of the transmitters at Lawrenceville, New Jersey, used in the short-wave transatlantic circuits, when supplying 15 kw., radiates in the direction of its corresponding receiving station as effectively as would a non-directive system of about 750 kw.

The transmitting antennas also give some directivity in the vertical plane, increasing the radiation sent toward the horizon and decreasing that sent at higher angles. It is not yet certain that vertical directivity is always advantageous, and this effect has not been carried very far.

At the receiving station, the radiated power has dwindled to a small remnant which must be separated from the static as far as possible, and amplified to a volume suitable for use in the wire telephone plant. Here again directive antenna arrays are of value. A receiving antenna system, sensitive only in a narrow geographical sector and that lying in the direction from which the signal arrives, excludes radio noise from other directions thereby scoring a gain of perhaps 40 fold (16 db.) in the power to which the signal may be amplified without bringing noise above a given value. It also

scores against noise which arises in the tubes and circuits used for amplification, since the combined action of the several antennas of the array delivers more signal to the initial amplifier stage where such noises originate.

Thus it is evident that transmitter power, transmitting directivity, receiving directivity, and quiet receiving amplifiers are of aid in providing signal transmission held as far as possible above the radio noise. In a well designed system, the relative extents to which these aids are invoked will depend upon economic considerations as well as upon the technical possibilities of the art.

At both the transmitting and receiving stations, at least three antenna systems are supplied for each circuit,—one antenna for each of the three frequencies normally employed. The design and arrangement of these are dictated by the requirements flowing from their uses. The purpose of the transmitting antenna is to concentrate as much power as possible in one direction. The purpose of the receiving antenna is to increase reception from the desired direction, and to cut down reception at all other angles. In the former, the forward-looking portion of the characteristic is of greatest importance, while in the latter, the rearward characteristics need greatest refinement.

Transmission Performance

In short-wave telephone systems, the width of the sidebands is so small a percentage of the frequency of transmission that tuning characteristics of the antennas and high-frequency circuits are relatively broad and impose little constriction on the transmission-frequency characteristic. Over the range of approximately 250 to 3000 cycles employed for these commercial circuits, a flat speech band is easy to obtain. This relieves the short-wave circuits from many of the problems of obtaining sufficient band width which are troublesome in designing long-wave systems.

Short-wave transmission is subject to one frailty which particularly hampers its use for telephony. This is fading. Where fading is of the ordinary type, consisting of the waxing and waning of the entire transmitted band of frequencies, automatic gain control at the receiving station is of value and is employed in the transoceanic circuits under discussion. The amplification in the receiver is controlled by the strength of the incoming carrier and is varied inversely with this strength so as to result in substantially constant signal output. Obviously this control can be effective only to the extent when the signal falls low enough to be overwhelmed by radio noise, which seldom happens.

When fading is of the selective type,—that is, the different frequencies in the transmitted band do not fade simultaneously,—the automatic gain control system is handicapped by the fact that the carrier or control signal is no longer representative of the entire signal band.

Selective fading is believed to result from the existence of more than one radio path or route by which signals travel from transmitter to receiver. These paths are of different lengths and thus have different times of transmission. Wave interference between the components arriving over the various paths may cause fading when the path lengths change even slightly.

If the path lengths differ by any considerable amount,—for example, a few hundred miles,—the wave interference is of such a character as to affect the frequencies across a band consecutively rather than simultaneously.

With the presence of selective fading there comes into being the necessity of guarding against rapid, even though small, variations in the transmitted frequency, since if such variations are present, a peculiar kind of quality distortion of the telephone signal results.

The varying load which speech modulation places on the transmitter circuits tends to cause slight variations in the instantaneous equivalent frequency, which are known as "frequency modulation" or "phase modulation" depending on their character. To prevent this effect, the control oscillator must be carefully guarded against reaction by shielding and balancing of circuits and the design must be such as to preclude variable phase shifts due to modulation in subsequent circuits of the transmitter.

It is apparent that if there are two paths of different lengths, two components which arrive simultaneously at the receiver may have left the transmitter several thousandths of a second apart. If the transmitter frequency has changed materially during this brief interval, trouble may be expected. The trouble actually takes the form of a distortion of the speech as demodulated by the receiving detector.[3]

Defects in short-wave transmission due to radio noise, minor variations in attenuation, fading, and distortion are nearly always present to some extent, and when any or all are severe, cause a certain amount of lost service time. These interruptions are of relatively short duration and furthermore, there is enough overlap in the normal times of usefulness of the several frequencies available so that shifting to another frequency may give relief. In addition, there is a kind of interruption which from the standpoint of continuity of service, is more serious. At times of disturbance of the earth's magnetic field, known as "magnetic storms," short-wave radio transmission is generally subject to such high attenuation that signals become too weak to use and sometimes too weak to be distinguishable. These periods affect all the wavelengths in use and may last from a few hours to possibly as much as two or three days in extreme cases. They are followed by a recovery period of from one to several days in which transmission may be subnormal.

Severe static may cause interruption to both long- and short-wave services at the same time,but the short waves are relatvely less affected by it and are usually

3. For a discussion of this phenomenon see "Some Studies in Radio Broadcast Transmission" by Bown, Martin, and Potter, *I. R. E. Proc.*, Vol. 14, No. 1, p. 57.

able to carry on under static conditions which prevent satisfactory long-wave operation. On the other hand, severe fading or the poor transmission accompanying a magnetic disturbance may interrupt short-wave service without affecting the long waves adversely,—in fact magnetic disturbances often improve long-wave transmission in the daytime. The service interruptions

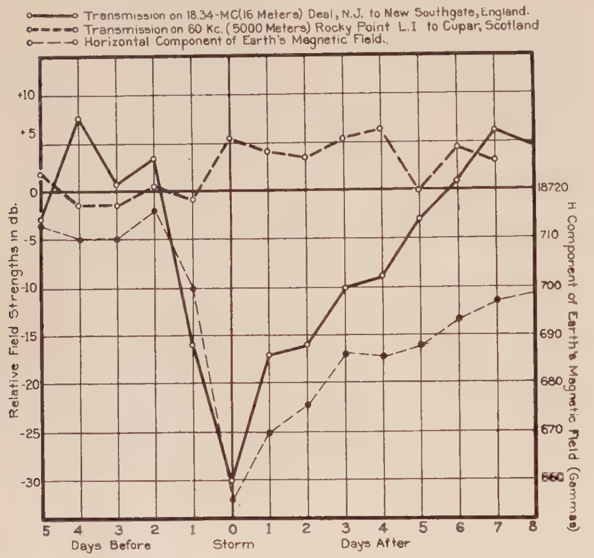

Fig. 2—Effect of Magnetic Disturbances on Radio Transmission

on the two types of circuits are thus nearly unrelated to each other and have no definite tendency to occur simultaneously. This is the principal reason why both long-wave circuits and short-wave circuits appear essential to reliable radiotelephone service.

On very long routes or those which cross tropical areas which result in static sources facing the directive receiving antennas, long waves cannot as yet be successfully employed and short waves alone are available. However, experience tends to indicate that on northern and southern routes, such as between North and South America, the interruptions associated with magnetic storms are less severe and of shorter duration.

The cycle of events which accompanied a particularly severe magnetic storm[4] in July, 1928, is shown graphically in Fig. 2. The light dotted curve shows the variation in the horizontal component of the earth's field. The heavy solid line follows the daily averages of the short wave received signal field. It is apparent that the disturbance took two days to reach its peak, and the recovery to normal took nearly a week. The heavy dotted line shows received field on long waves (60 kilocycles) and indicates that transmission was improved slightly at the same time the short waves were suffering high attenuation.

The experience with transatlantic telephone service on short waves covers a period of nearly three years, there having been available a one-way channel from the United States to England used as an emergency facility for the first year and a half, a two-way circuit for the next year, and two circuits since June, 1929. It is only in this later period, however, that a circuit has been available, operating regularly with the amounts of transmitter power and antenna directivity which have been mentioned.

The performance of the two one-way channels forming this circuit is charted in Fig. 3. The charts are plotted between hours of the day and days in the year, so that each unit block represents one hour of service time. The solid black areas are time in which commercial operation could be carried on. The dotted

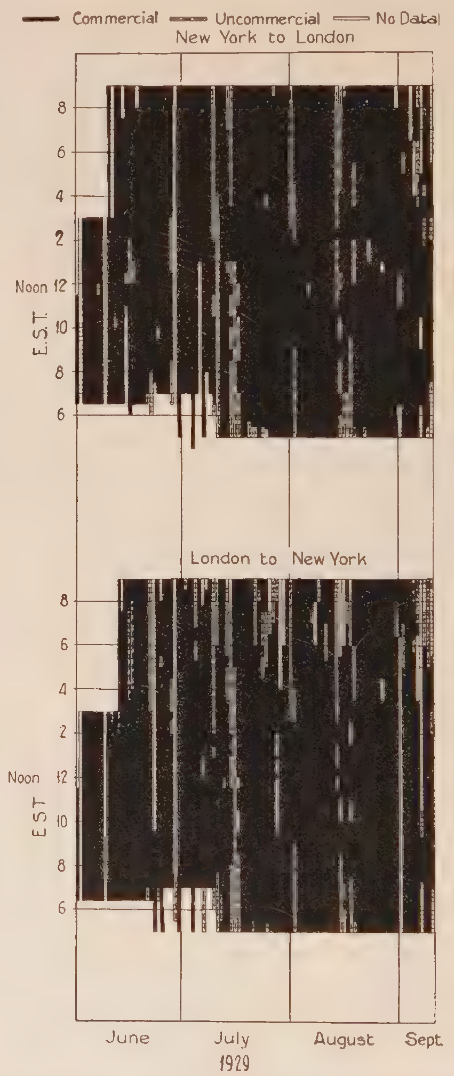

Fig. 3—Chart showing Transmission Performance of a Short-Wave Transatlantic Telephone Circuit

strips are uncommercial time. The blank areas are for time in which, for one reason or another, the circuit was not operating and no data were obtained. Perhaps the most outstanding feature of these charts is the tendency of the lost time to fall in strips over a period of two or three days. These strips coincide approximately for both directions of transmission. The principal ones are about July 10, 15 and August 2 and 17. These are

4. Data regarding other magnetic disturbances are given in a paper by C. N. Anderson, entitled "Notes on the Effect of Solar Disturbances on Transatlantic Radio Transmission," *I. R. E. Proc.*, Vol. 17, No. 9, September, 1929.

characteristic of the interruptions accompanying magnetic disturbances of the kind which occur at irregular intervals of a few days to several weeks. They are of course not so severe as the disturbance illustrated in Fig. 2.

It is apparent that for these three summer months, this new circuit gave a good account of itself and furnished commercial transmission for something like 80 per cent of the time that service was demanded of it. In these same months, the long-wave system suffered its greatest difficulty from static, and we have concretely illustrated the mutual support which the two types of facilities give each other.

It should not be inferred from these data that the short-wave transatlantic radio links furnish, 80 per cent of the time, talking circuits as stable and noise-free as good wire lines. Under good conditions, they do provide facilities which compare favorably with good wire facilities; on the other hand, they may at times be maintained in service and graded "commercial" under conditions of noise or other transmission defects for which wire lines would be turned down for correction, since the obviously undesirable alternative is to give no service at all until conditions have improved again. The present development effort is largely directed toward improvements which will insure not only a greater degree of reliability against interruptions but which also will improve the grade of service as a whole.

Abridgment of

Lightning Investigation on Transmission Lines

BY W. W. LEWIS* and C. M. FOUST*
Member, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*The surge voltage investigations, 1926 and 1927, are briefly reviewed, and data given for 1928 and 1929. The cathode ray oscillograph has played a prominent part in the last two year's work, and about 115 oscillograms have been obtained. The following new instruments were introduced in 1929: Lightning stroke recorders; field intensity recorder; and rate of change of field intensity recorder. A vast amount of progress has been made in the solution of the lightning problem. Personnel, equipment, and technique are available for the complete solution of the problem by means of field and laboratory studies, carried on simultaneously and supplementing each other.*

* * * * *

A *Symposium on Surge Voltage Investigation* covering mainly the work done in 1926 and 1927, was presented at the annual convention of the A. I. E. E. at Denver in June 1928.[1]

Tentative conclusions were drawn as to polarity and magnitude of surges, wave shape, and attenuation, and it was stated that during the coming year, special efforts would be made to obtain data on wave shape, attenuation, effect of ground wires, and effect of lightning arresters and choke coils.

Now two years' additional data have been accumulated and we can answer some of the questions which were unanswered at the Denver Convention.

In the present paper, the 1928 and 1929 work will be discussed and an effort will be made to summarize the present status of the investigation and to outline the future work.

I. Crest Values of Surge Voltages Due to Lightning and Switching

In Figs. 1, 2, and 3 are plotted the surge voltages caused by lightning during the years 1927, 1928, and 1929 respectively. The abscissas represent times normal crest line-to-neutral voltage, and the ordinates represent percentage of the total number exceeding the value indicated by the abscissas.

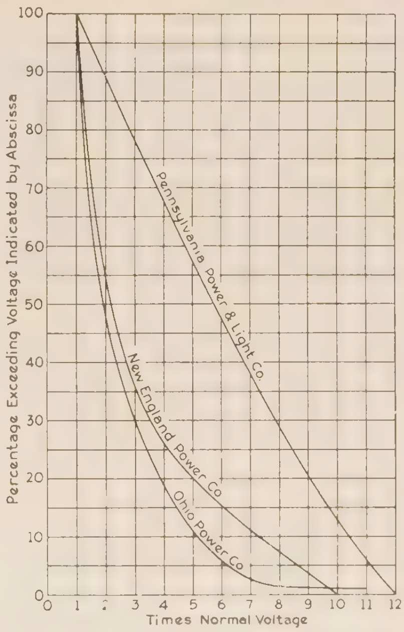

Fig. 1—Values of Surge Voltages Caused by Lightning, 1927

II. Trip-outs Caused by Lightning, and Flashed Insulator Strings

The number of surges caused by lightning, as measured by the surge voltage recorder, is given for the

*Both of General Electric Co., Schenectady, N. Y.

1. *Symposium on Surge Voltage Investigation*, by W. W. Lewis, E. W. Dillard, J. G. Hemstreet and J. R. Eaton, P. Sporn, and N. N. Smeloff, A. I. E. E. Trans., Volume 47, No. 4, 1928, page 1111.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

years 1926, 1927, 1928, and 1929 for the three systems under discussion, in Table IV; also the number of line trip-outs. The data on the number of surges are given for the portion of the year indicated in the last column of the table, while the data for the trip-outs cover the whole year. It is evident that there are many more surges recorded than there are trip-outs.

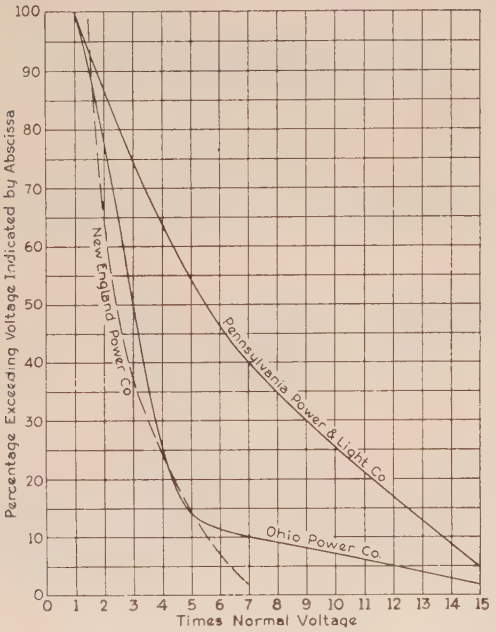

Fig. 2—Values of Surge Voltages Caused by Lightning, 1928

Data compiled on these systems also show that there are as many as from 1 to 5 insulator strings or assemblies flashed over for each tripout. In other words, each stroke which causes a flashover usually affects more than one string or assembly, either on the same tower or on adjacent towers.

Statistics also indicate that where there are two circuits on a tower, from 5 to 25 per cent of the strokes affect insulator strings on both circuits.

III. Wave Front and Wave Shape

A cathode ray oscillograph was installed in the lightning laboratory on the Pennsylvania System at Wallenpaupack (Tower 1-3) during the latter part of 1928 season, and one oscillogram was obtained of a lightning surge.[7] The surge was positive in polarity, rose to maximum in 8 microseconds, reduced to 50 per cent of that value in 17 microseconds, and to zero in 35 microseconds. The crest voltage of the main wave was approximately 600 kv. At a point 17 mi. from the laboratory, a value of 2100 kv. was measured by surge voltage recorder.

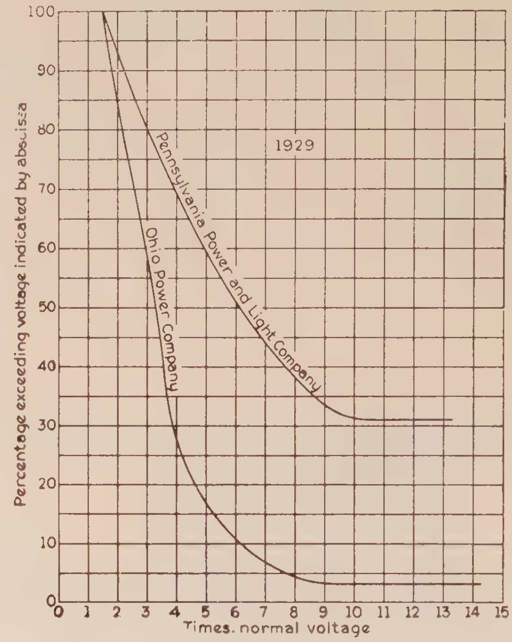

Fig. 3—Values of Surge Voltages Caused by Lightning, 1929

In 1929 the cathode ray oscillograph installation (Fig. 4) was continued at Wallenpaupack, and in the course of the season, 95 surges were recorded. Of these there were 50 surges under 100 kv., 30 between 100 and 300 kv., and 15 over 300 kv. at the laboratory. Table V summarizes the data for the oscillograms taken up to August 11, 1929, with voltage magnitudes between 100 and 300 kv. These are typical of all surges recorded in this voltage classification.

In Table VI are summarized data for the 15 oscillo-

TABLE IV

NUMBER OF SURGES AND NUMBER OF TRIPOUTS CAUSED BY LIGHTNING

System	Rated voltage kv.	Line length miles	Number of surges caused by lightning measured by surge voltage recorders				Number of line tripouts caused by lightning				Period during which surge voltages were measured
			1926	1927	1928	1929	1926	1927	1928	1929	
Pennsylvania Power and Light Co.	220	65	33	48	28	45	16	7*	14	38	1926 July 20–Oct. 4 1927 Mar. 12–Nov. 2 1928 April 15–Oct. 1 1929 April 17–Oct. 1
Ohio Power Co.	132	73	..	166	46	31	15	4	12	11	1927 May 11–Oct. 16 1928 April 29–Oct. 20 1929 May 6–Oct. 1
New England Pr. Co.	110	74	14	104	47	..	11	43	5	13	1926 July 28–Sept. 12 1927 June 6–Oct. 10 1928 June 23–Oct. 8

*Line out of service two months during lightning season, installing ground wires.

Note: Tripouts are given for the whole year while surges were recorded for only a portion of the year as noted in last column. Ohio Power and New England tripouts are for two circuits.

7. "Transmission Line Insulation and Field Tests Pertaining to Lightning," W. W. Lewis, *General Electric Review*, July 1929.

grams with voltage magnitude exceeding 300 kv. It will be noted that the voltage magnitudes in this classification range from 330 to 1260 kv. The wave front ranges from 1.6 to 36 microseconds. Two of the

Fig. 4—Interior View of Wallenpaupack Laboratory

Showing two General Electric portable cathode ray oscillographs

oscillograms obtained could not be analyzed for wave front, because of improper adjustment in the oscillograph arrangement. The total duration varied from 4

TABLE V
PENNSYLVANIA POWER & LIGHT CO. CATHODE RAY OSCILLOGRAMS 100 TO 300 KV., YEAR 1929, UP TO AUGUST 11

				Time in microseconds to reach			
Oscillogram number	Kv. max.	Polarity of first loop	Nature of wave	At least 75% of max. voltage recorded	Max. voltage recorded	50% max. on tail of wave	Zero of first loop
901178	245	Pos.	Uni.	0–1.2	0–1.2	22	33 +
179	160	Pos.	Osc.	0–1	5	13	24
183	180	Pos.	Osc.	5	5	23	32
187	260	Pos.	Uni.	0–1	5	26	45 +
189a	180	Pos.	Uni.	0–1.5	5	20	45 +
189b	140	Neg.	Uni.	0–1.5	10–28	45 +	45 +
190	280	Pos.	Osc.	4	4	11	20
191b	250	Pos.	Osc.	0–1.3	3	5.5	9.5
197	180	Pos.	Osc.	0–1	6	27	35
198	150	Neg.	Uni.	0–1.5	4	45 +	45 +
199	180	Pos.	Osc.	2.5	4.5	18	26
200	260	Pos.	Osc.	5	5	27	36
201a	130	Pos.	Osc.	3	3	11	33
203	260	Pos.	Osc.	2	5	25	35
204	170	Pos.	Uni.	0–1	20	43 +	43 +
214	135	Neg.	Osc.	0–2	0–2	6	10

Osc. = Oscillatory.
Uni. = Unidirectional.

to 75 microseconds. Approximately 60 per cent were positive and 40 per cent negative for the first loop. Within the time range of the oscillograms obtained, two-thirds of the waves were oscillatory and one-third unidirectional.

VI. Lightning Stroke Recorders

In 1929 lightning stroke recorders were placed in service on 284 of the approximately 300 towers of the Wallenpaupack-Siegfried line, and on about 20 towers of the Philo-Canton line.

Fig. 12 shows the recorder, which is a small Lichtenberg camera, placed across a portion of a leg of a transmission tower. The development of the instrument and its application are due to Mr. W. L. Lloyd, of the Pittsfield High-Voltage Laboratory.

Four figures were obtained,—two on the Wallenpack-Siegfried line and two on the Philo-Canton line.

TABLE VI
PENNSYLVANIA POWER AND LIGHT CO. CATHODE RAY OSCILLOGRAMS OVER 300 KV., YEAR 1929

				Time in microseconds to reach		
Oscillogram number	Kv. max.	Polarity of first loop	Nature of wave	Max. voltage recorded	50% max. on tail of wave	Zero of first loop
901180	1260	Neg.	Osc.	3.3	3.7	4 Flashover
185	360	Pos.	Uni.	4	45 +	45 +
186	330	Pos.	Osc.	1.6	16	29
188	530	Pos.	Osc.	7–8	18	24
191	600	Neg.	Uni.	4	14.5	45 +
193	740	Pos.	Osc.	7	16	22
194	810	Neg.	Osc.	36	?	37 Flashover
201	740	Neg.	Uni.	6.5	43 +	43 +
229	330	Neg.	Uni.	?	12	75
231	330	Pos.	Osc.	?	18	25
249	390	Pos.	Osc.	6	14	18
251	390	Pos.	Osc.	6	35	55
272	600	Neg.	Uni.	< 7.5	69 +	69 +
275	500	Pos.	Osc.	< 8	32	45
285	630	Pos.	Osc.	11	20	29

Osc. = Oscillatory.
Uni. = Unidirectional.

VII. Field Intensity Recorder and Rate of Change of Field Intensity Recorder

In an effort to obtain some measurements with regard to electric field conditions to which transmission conductors might be subjected, two instruments were built and placed in operation at the Wallenpaupack laboratory. These instruments are called, respectively, a field intensity recorder and a rate of change of field intensity recorder.

The instruments were developed and applied under

Fig. 12—View of Lightning Stroke Recorder

the supervision of Mr. H. B. Marvin of the General Engineering Laboratory, Schenectady, who also analyzed the data obtained.

The purpose of the field intensity recorder is to obtain a photographic record on motion picture film of the vertical component of electric field intensity (voltage gradient) versus time. The purpose of the rate of change recorder is to obtain a photographic record of the vertical component of the time rate of change of electric field intensity. The adjustment is made so that only relatively large values, such as occur during thunder storms, are recorded. The data so obtained are expected to be helpful in two ways: (a) to acquire further knowledge of the nature of lightning storms; (b) in measuring the relative severity of thunder storms.

Fig. 15 shows a view of the field intensity recorder and

Fig. 16 shows a typical record taken with this instrument; also a record obtained at the same time with the rate of change of field recroder.

Records obtained from the field intensity recorder

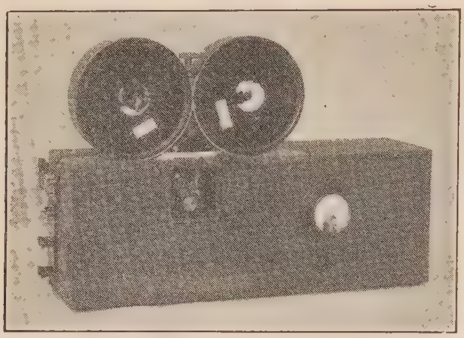

Fig. 15—View of Field Intensity Recorder

were measured, and the data plotted for each storm on cross-section paper, the abscissas representing time and the ordinates kilovolts per meter. Fig. 17 shows the data for the storm of June 19, 1929.

A study of the records indicates that the readings

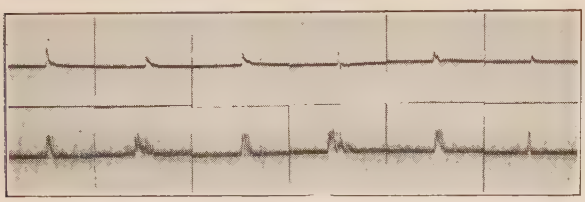

Fig. 16—Typical Record Obtained with Field Intensity Recorder (Upper) and with Rate of Change of Field Recorder (Lower)

for any one storm are usually of one predominant polarity, which may be either positive or negative. Of 33 storm periods studied, about 40 per cent gave

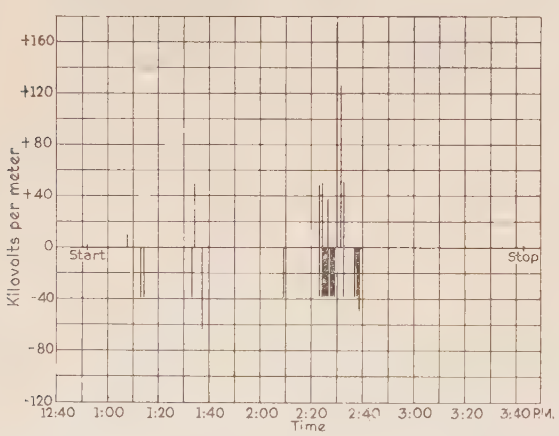

Fig. 17—Field Intensity Data Obtained by the Field Intensity Recorder during the Storm of June 19, 1929

readings predominantly positive, about 40 per cent predominantly negative and about 20 per cent mixed positive and negative.

VIII. Conclusions

A vast amount of progress has been made in the study of the effects of lightning on transmission lines in the past two years.

Upper limits of 15.2 times normal voltage for lightning surges and 5.5 times normal for switching surges have been reached.

Gradients as high as 52 kv. per ft. of height have been recorded on transmission lines, and 85 kv. per ft. on special antenna.

Trip-outs have occured on the lines under investigation as high as 29 per 100 mi. per year, with 3.6 flashed insulator assemblies per tripout.

About 115 cathode ray oscillograms of natural lightning were obtained on the Pennsylvania, Ohio, and Consumers Power systems, ranging from low values to 1260 kv. Wave fronts varied from less than one to 36 microseconds and total duration of first loop from about one to 75 microseconds. Unidirectional waves predominated and positive polarity.

The formulas developed from the 1927 results for attenuation[9] have geen substantiated, both by results from natural lightning and from artifiicial lightning. The factor k for natural lightning has been found to average 0.00016 on the New England and Pennsylvania systems; for Ohio the factor is 0.00057. Artificial lightning surges on the Michigan system gave a factor of the order of 0.00044 and on the Turners Falls system of the order of 0.00069.

Attenuation apparently varies with the size of conductor, with the steepness of wave front, with the polarity the wave, with the presence or absence of ground wires, and possibly with other factors.

The value of overhead ground wires in reducing induced potential and in reducing tripouts has been demonstrated by test and by operating experience.

Lightning stroke recorders have been introduced and a few records obtained. These give promise of much usefulness in the future.

Field intensity recorders and rate of change of field intensity recorders have been used and data of considerable value obtained. Gradients as high as 85 kv. per ft. have been recorded. These instruments promise to yield a good deal of information about the habits of storms.

The intensive observation of storm conditions at the Pennsylvania lightning laboratory indicated that in 1929 there were 24 cloud-to-ground strokes within a one-mile radius in this vicinity.

In the future work, an attempt will be made to differentiate between the surges and flashovers due to induced strokes and direct strokes. An attempt will be made to record by cathode ray oscillograph the wave shapes of some of the extremely high voltages which have been found by surge voltage recorder. The effects of counterpoises or grounded conductors under the transmission line will be studied. Attenuation will be studied further with both natural and artificial lightning. Devices to prevent flashover (line type arresters) will probably be tried out experimentally during the coming year.

Abridgment of

Fused Grading Shields

BY H. A. FREY[1] and E. M. SKIPPER[1]

Associate, A. I. E. E. Non-Member

Synopsis.—*The fused grading shield was developed primarily to reduce the number of outages due to insulator flashovers on transmission lines. Recent practise of reducing the insulation adjacent to terminals has increased the number of flashovers in these sections. The fused grading shield, while not always economically feasible for entire lines, provides a means of obtaining the reduced insulation without increased outages.*

Laboratory and field data are presented showing the characteristics of the device as well as the results of several years of operating experience.

THE use of fuses in conjunction with grading shields and arcing horns was first tried on two circuits of the Columbia-Terminal Station line of the Union Gas and Electric Company in the Spring of 1927. The device as at first installed has been very completely described by Mr. Philip Stewart of the Union Gas and Electric Company in previous papers.[2] It consisted of the usual grading shield and arcing horn combination except that the grading shield was insulated from the line by two standard suspension units. These two units were then short-circuited by means of a high-voltage fuse of the carbon tetrachloride type. In the event of a flashover of the insulator string, the arc formed between the grading shield and the top arcing horns, forcing the ground current to flow through the fuse. The operation of the fuse extinguished the arc by disconnecting the grading shield from the line. This operation was so rapid that no line outage occurred.

This device operated so successfully during the 1927 lightning season that in 1928 the company decided to equip the two circuits remaining between Columbia and Terminal Stations with similar equipment. The original fused grading shields, requiring as they did two additional insulator units per string, were not particularly economical. The redesigned assemblies eliminated this feature. The grading shield was placed in its usual position at the bottom of the string with fuses in place of arcing horns at the ground end. Expulsion type fuses replaced the carbon tetrachloride fuses and with this set up it was found possible to use two fuses per assembly in place of one. Tests showed that except in rare cases, no arc would strike to both fuses at once. This, of course, meant that after one operation, there would still be one fuse available in the event of further trouble at the same point.

The 1928 operating experience on this line was again very favorable and has been completely reported by Mr. Stewart.[4]

The adoption of the double-ended expulsion type of fuse which is now standard on fused grading shield assemblies was the outcome of a large number of short-circuit tests using various shield and fuse combinations.

Coincident with these tests, a number of impulse tests was also run to determine the correct setting of the grading shield and fuses, in order to assure the formation of the arc between the shield and the tips of the fuses. The tests which were made for this purpose were conducted using an impulse of very steep wave front and with a tail falling to one-half crest value in about five microseconds. This type of wave, having a very steep front, is more severe from the standpoint of cascading than the usual wave encountered in practise. Obviously if the arc cascaded the insulator string and failed to strike to the fuse, the entire object of the device would be defeated.

It was found that if the arcing distance between fuse and shields did not exceed 80 per cent of the striking distance across the unshielded string, satisfactory arc clearing characteristics could be expected.

The foregoing tests, of course, all fall under the general heading of Development Tests but a number of tests have also been made to determine the operating characteristics of the device. These tests have been conducted both in the high-current testing laboratory of the General Electric Company and in the field. On all of the short-circuit tests the arc was originated by means of a piece of fine fuse-wire string between the fuse tips and the shield. Table I of the complete paper gives a summary of these tests. Out of 21 tests, there were two arcs which failed to clear or, ignoring the laboratory tests, two out of fifteen. On both of these tests, the available current was very small. The time required for any fuse to operate and clear the circuit becomes greater as the short-circuit current decreases. With currents of the order of 100 amperes, the time required for the fuse to clear is so great that even moderate winds are likely to blow the arc away from the fuse tips and onto the tower hardware in which position it is of course beyond the control of the fuse. This is what happened in the two cases in question. 200 amperes appears to be the minimum current limit for satisfactory operation of the fused grading shield. The upper limit of short-circuit current has not as yet been determined, but tests have been made with short-circuit currents as high as 5120 amperes with perfect success.

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1. Locke Insulator Corp., Baltimore, Md.
2. Report to Overhead Systems Committee of N. E. L. A. presented in Chicago in October 1927.
3. *Fused Arcing Horns and Grading Rings*, by P. Stewart, A. I. E. E. TRANS., Vol. 48, July, 1929, p. 891.
4. Philip Stewart, *Fused Arcing Hours and Grading Rings* Cincinnati Regional Meeting July, 1929, Quarterly TRANS., Vol. 48, p. 891.

Presented at the North Eastern District Meeting of the A. I. E. E., Springfield, Mass., May 7-10, 1930. Complete copy upon request.

Figs. 1, 2, and 3 are respectively the oscillograms taken during tests 17, 19, and 21.

In addition to the tests listed in this tabulation, a series of tests were conducted by the Carolina Power and Light Company at the Swannanoa Substation near Asheville, North Carolina. Unfortunately no oscillo-

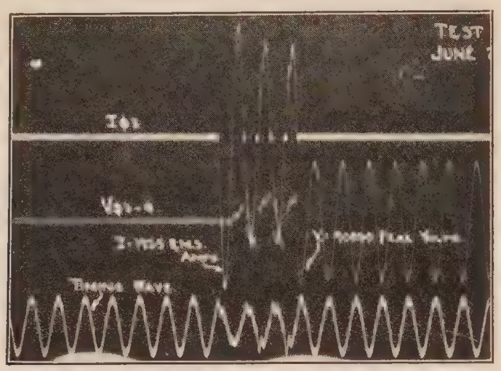

Fig. 1

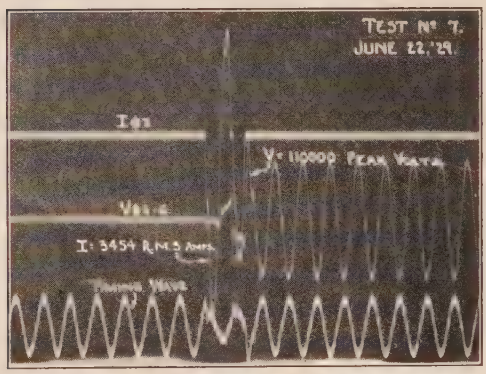

Fig. 2

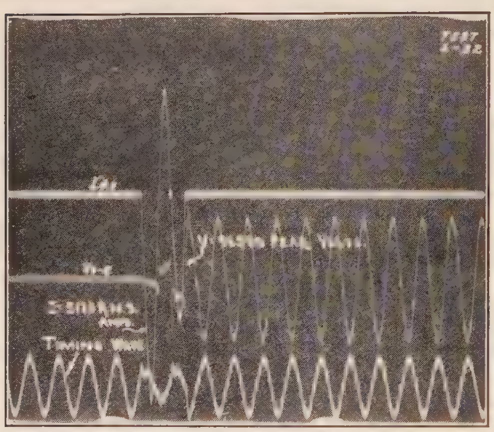

Fig. 3

Figs. 1, 2, and 3—Oscillograms Obtained during Field Tests

Showing short-circuit current and time to clear.

graph was available to accurately record the current and duration of the arc. It is estimated, however, that the short-circuit current of the system at this point is around 250 amperes. The system voltage is 66 kv.

The four-fuse grading assembly was used for this test. Seven arcs were started all of which cleared successfully without operation of the line relays. During one short circuit, two fuses were blown. In this case, the wind carried the arc from the tip of the fuse from which it had started to the tip of an adjacent fuse. An attempt was made to repeat this on succeeding tests by starting the arc on the windward side. Despite this, no further example of more than a single-fuse operation occurred.

Fig. 5 shows the fused grading shield during another field test, clearing a ground current of 2878 amperes. The flame is quite clearly being ejected from both ends of the tube. It will also be noted that the original arc between the tips of the fuse and grading shield is remaining well clear of the insulator string.

The modern tendency in transmission line design is largely towards the over insulation of the line with a view to reducing the number of outages caused by insulator flashover. This practise has resulted in improved line service; but where the path of the storm

Fig. 5—Fused Grading Shield in Operation during One of Field Tests

is close to a line terminal, it has in many cases merely shifted the burden to the substation apparatus. It is relatively easy, and for the higher voltages, at least, relatively inexpensive, to add a few units to an insulator string. On the other hand, it is very difficult and expensive to attempt to raise the insulation of the substation apparatus to the level of the increased line insulation. It has, therefore, become customary to reduce the line insulation immediately adjacent to the terminal to a value which will balance with the terminal equipment insulation.

Due to the rapidity with which lightning surges on transmission lines are attenuated, most disturbances originating several miles out on the line will probably be reduced below dangerous proportions before they reach the reduced insulation. Nevertheless, there will naturally be an increased number of flashovers adjacent to the terminals, resulting in a corresponding increase in number of line outages. There is also the added danger

of damaging the insulator units at this point, thus causing a prolonged outage while repairs are being made. The use of a standard grading shield on the shortened strings will prevent the insulator damage, but cannot prevent the line trip-out when flashover occurs.

If the fused grading shield is applied to the reduced insulation at the terminals, and the gap between the fuse tip and shield adjusted to give the desired flashover voltage, then the excess voltage on the line will be relieved without an outage, since the power current to ground is interrupted by the fuse without operation of the line relays. Unlike the lightning arrester, the fused grading shield may be expected to care for only such surges as are of sufficient magnitude to arc the gap. The lightning arrester would protect the station equipment from the hammer blows of smaller transients.

For this class of service, a fused grading shield has been developed, equipped with four fuses so that each assembly is capable of clearing four arcs without fuse renewal. Two- and three-fuse assemblies have also been applied to this service to fit special conditions.

These reduced gaps should be installed on each line for a distance of approximately ¼ mile out from the terminal. A number of installations have been made equipped with but a single gap on each line wire. So far no difficulties have resulted from the use of this single gap but as an additional safety factor, it is certainly advantageous to have more than one gap on each conductor.

It is important to remember that the last gap adjacent to the terminal should be placed as close to the apparatus to be protected as possible; otherwise it is quite likely that reflections will so build up within the substation that it will result in breakdown or arc-over of the apparatus without affecting the fused grading shield.

In Table II is listed the proper gap setting of a fused grading shield to balance with modern substation equipment. Here again it must be remembered that much of the older equipment was designed with lower insulation than that which is now being used. Hence, in some cases it may be necessary to use a still smaller gap in order to balance with this old substation insulation. In many cases the switch insulators or bus supports in the substation constitute the weak link. When such is the case, it may be necessary to set the reduced gap below the tabulated values in order to prevent flashover or disconnect switches and bus supports.

TABLE II—GAP SETTINGS TO BALANCE WITH STANDARD STATION EQUIPMENT

Line voltage in kv	Fused grading shield gap in in.	Approximate impulse FO of gap	Approximate 60-cycle flashover of gap
33	10 in.	310	103
66	21 in.	605	206
88	31 in	900	290
110	37 in.	1060	345
132	41 in.	1170	380

The double-ended expulsion fuse which was chosen for use with fused grading shields presents several unique features.

The fusible link of this fuse is placed at the upper end of a weatherproof fiber tube. To the lower end of the line is fastened a long copper pigtail which runs the entire length of the tube. The pigtail is held taut by a compression spring at its lower end. The tube is capped at either end; the cap on the lower end is held in place by friction, but the cap at the upper end is sweated in. When the fusible link is melted, the compressed spring is released. The combination of forces of the released spring and of the gases generated in the tube blow out the cap and vent the tube, extinguishing the arc.

With the expulsion type of fuse, it is desirable to build up the internal gas pressure promptly in order to obtain quick clearing. With the double-ended fuse only the lower cap opens on low current operation so that there is no loss of pressure from the upper end of the fuse. The spring also aids in obtaining quick clearing under low currents, since it hurls the copper pigtail free of the fuse tube as soon as the fuse element melts. The maximum current rupturing capacity of an expulsion fuse may be the point at which the fuse tube bursts due to excessive pressure. When the internal pressure becomes excessive in a double-ended fuse, the upper cap is blown out and the tube is vented from both ends. The double-ended action is particularly desirable for fuses used on fused grading shields, since it reduces the unbalanced reaction. In rupturing high currents, this unbalanced reaction might otherwise become sufficiently severe to give a violent kick to the supporting insulators.

During the high-current tests, the expelled elements were thrown about 30 ft. from the insulator string.

Further tests were made to determine the point at which corona formation would start about the copper pigtail in the fuse tube. It was found that with a standard 110-kv. fused grading shield of the two-fuse type mounted on an eleven unit string, the corona point was 82 kv. when the fuses were parallel to the conductor. With the fuse at right angles to the conductor, the corona point was 89 kv. The normal corona point on the standard grading shield assembly would be in the vicinity of from 90 to 95 kv.

Operating Experience

Since the installation of the first fused grading shield in actual service, an attempt has been made to keep an accurate record of its performance.

Table III represents a summary of the operating characteristics of those fused grading shields which have been installed during the past three years. The table shows the approximate short-circuit currents to ground, the number of failures to clear and the number of cases of damage to substation apparatus protected by the fused grading shield and damaged to the insulators on which the fused grading shield is mounted. Four trip-outs which may have been caused by arcs on the fused

grading shield are also listed. Only the operations on the Union Gas & Electric Company's system which have not been previously reported by Mr. Stewart are included in this table. Lightning arresters were not used on any of the installations listed in Table III.

The only case of flashover or damage to the substation equipment to be protected is that reported by the Pennsylvania Water and Power Company, where there have been four bushing flashovers since the fused grading shields were installed. Two of the bushings flashovers occurred simultaneously, one at each end of the line, apparently as a result of the same surge. In an effort to prevent a repetition of this, the gap was reduced somewhat. After the reduction there were two more bushing flashovers. These occurred during an exceptionally bad lightning season during which a large number of fuses were blown on this same system. There is little doubt that had no fused grading shields been installed, the number of substation flashovers would have been considerably greater.

On this system, each end of each line wire is provided with fifteen reduced gaps. This probably accounts for the large number of fuse operations shown on the operating records. The bulk of these fuse operations occurred during the second season.

The installation of fused grading shields on the Memphis Power and Light Company's North Memphis, Ripley and Covington Substation is of the four fuse type. The distance from North Memphis to Covington is 26 mi. and from Covington to Ripley 14 mi. There have been two cases of fuse operation, each accompanied by a line trip-out. The first operation resulted in the blowing of all fuses on all line wires at North Memphis, a total of 12 fuses on one line wire at Covington and one fuse on each of two line wires at Ripley. Apparently these operations were due to the same surge.

Both of these surges must have been very severe in order to have arced so many gaps. The line trip-outs were undoubtedly caused by the flashover of other insulator strings out on the line which were not protected by fused grading shields.

On the installation at the Minnesota Power and Light Company's Nashwauk Substation there has been one fuse operation and a simultaneous line trip-out. This line trip-out is believed to have been due to the arc at the fused grading shield but it is possible that it may have been due to another flashover out on the line on an unprotected insulator string.

TABLE III—OPERATING DATA

Operating company	Line or substation	System voltage	Ground current amperes	Connected capacity kv-a	No. of gaps on each line wire	Distance nearest gap to apparatus to be protected	Date put in operation	No. of operations	No. of failures to clear	No of cases of insulator damage	No. of case of F. O. of substation apparatus	No. of trip-outs of line relay
Memphis Pr. & Lt.	N. Memphis Ripley & Covington Stations	66 kv.	500 to 800		1	100-400 ft.	June or July 1929	2	None	None	None	2
Minn. Pr & Lt.	Hibbing Substa.	110 kv.	415 to 920	72,000 kv-a.	3	100 ft.	May 27 1929	1	"	"	"	0
Minn. Pr. & Lt	Nashwauk Substa.	110 kv.	422–1033	72,000 kv-a.	3	200 ft.	May 27, 1929	1	"	"	"	1
Union Gas & Elec. Co.	Hartwell Substa.	66	1500–2000	285,000 kv-a.	On all towers	200 ft.	May 1928	4	"	"	"	0
Penna. Water & Pr. Co.		70 kv	300–600	16,000	15	40–75 ft.	Spring 1928	95	1	1	4	1
Carolina Pr. & Lt. Co.	Swannanoa Substa.	66 kv.	250–300	90,000	1	70	April 1929	8	None	None	None	0
Carolina Pr. & Lt. Co.	Brisco Sub-sta.	110	About 500	108,000	1	2500–3000 ft.	Sept. 1929	2	"	"	"	0

It is interesting to note that none of the operating companies have reported any trouble arising from the recovering voltage after a fuse operation. In addition to the operations listed in Table III, Mr. Stewart has already reported seven interruptions, and twelve interruptions prevented by the fused grading shields on the Union Gas and Electric System. Some of the fuses on this system are of the carbon tetrachloride type and some, of the single-ended expulsion type. None of the double-ended fuses are in use on the Union Gas and Electric System.

Summary

1. The minimum short-circuit current which the fused grading shield, using a double-ended expulsion fuse can be expected to satisfactorily clear is about two hundred amperes.

2. The maximum short circuit which can be cleared has not been determined but it is in excess of 5100 amperes.

3. Out of a total of 28 tests made in the laboratory and in the field there have been two cases of failure to clear. Both of these were with currents under 200 amperes.

4. Operating records show that out of a total of 113 operations on modern assemblies in service, there has been only one failure to clear, with consequent damage to line insulators, and four cases of flashover within the substation. There have been four cases in which the line has tripped out simultaneously with a fused grading shield operation. Of the four, two on the Memphis Power and Light Company system were probably due to other flashovers on unprotected strings. This leaves two cases of line trip-out for which the fused grading shield is probably responsible.

Notice of Annual Meeting of Institute

Constituting a session of the Annual Convention of the Institute, the Annual Meeting of the American Institute of Electrical Engineers will be held at the Royal York Hotel, Toronto, Ontario, Canada, Monday morning, June 23, at 10:30 o'clock.

At this meeting, the Annual Report of the Board of Directors, the Report of the Committee of Tellers on the ballots cast for the election of officers, and the Report on the ballots case for Constitutional Amendments, will be presented.

Such other business, if any, as may properly come before an annual business meeting may be considered.

F. L. HUTCHINSON,
National Secretary.

Northeastern District Meeting

An excellent meeting of the Northeastern District will be held at the Hotel Kimball, Springfield, Mass., May 7-10.

An exceptionally fine technical program of unusual engineering papers on both the theory and practise of electrical engineering will comprise five sessions—one on instruments and measurements, one on transmission, two on electrical machinery, and one on selected subjects. All engrossing entertainment, interesting inspection trips, and good facilities for golf and tennis are also offered by an enthusiastic General Meeting Committee to all who attend.

A complete program and detailed account of the meeting was published in the April issue of the JOURNAL, pages 315-318 inclusive.

The A. I. E. E. Summer Convention

TORONTO, CANADA—JUNE 23-27

The Summer Convention will be held this year for the first time in Toronto, and many members who have not hitherto visited that city will find there much of unusual interest. Toronto is spread out along the shores of Lake Ontario, which is a link in the great fresh-water chain extending from the Atlantic to the heart of the continent; thus it offers much of interest in connection with inland navigation as well as aquatic sports of all kinds. Also, the city is located within convenient traveling distance of the most densely populated portions of the United States.

The Royal York Hotel, which will constitute convention headquarters, has been operating just about one year. It compares favorably not only in all general particulars with the latest and best of new hotels anywhere, but has a whole floor devoted to special convention rooms. It is in direct communication with the Union Station and overlooks the Harbor and Lake Ontario.

A selection of excellent technical papers covering various phases of the electrical industry has been made from a wealth of material. This material will be presented in eight technical sessions as follows: Protective Devices—Symposium on Transmission Line Relays III; Transportation; Automatic Stations; Selected Subjects and Technical Committee Reports; Transmission; Symposium on Coordination of Line, Station, and Apparatus Insulation; Communication; and Electrical Machinery and Power Generation.

A few of the subjects are; the 220-kv. system of the Hydro-Electric Power Commission; vertical shaft, 25,000-kv-a. synchronous condensers; hydro-power practise in central Europe; control systems for oil and gasoline electric locomotives; a 1000-kw. automatic rectifier; and centralized control of system operation.

The annual reports of the Technical Committees of the Institute will review the advances in theory and practise throughout the year.

The business side of the Convention will include the Annual Meeting of the Institute, a report of the Committee of Tellers on election of officers for 1930-1931, and a report on Constitutional Amendments, the President's Address and presentation of prizes for papers.

The Conference of Officers and Delegates, under the auspices of the Sections Committee and Committee on Student Branches, constitutes an important feature of the convention.

The Lamme Medal, awarded several months ago, will be presented to Mr. R. E. Hellmund, East Pittsburgh, Pa., "for his contributions to the design and development of rotating machinery."

On Wednesday there will be a Directors' Luncheon and meeting.

The program being prepared should leave nothing to be desired, both from the standpoint of professional benefit and of general social enjoyment. The Meetings and Papers Committee have prepared a schedule of papers covering a wide diversity of interest, the local Convention Committee has arranged a series of events which will provide interest and pleasure for all available time throughout the entire Convention. Particularly should it be noted that the following program calls for the Convention to get into full swing on Monday morning; members are urged to arrive early and register promptly.

OUTLINE OF PROGRAM

(Eastern Daylight Saving Time)

MONDAY, JUNE 23

9:00 a. m. Registration
10:30 a. m. Annual Business Meeting of the Institute
Address of Welcome
Annual Report of Board of Directors (in abstract), F. L. Hutchinson, National Secretary
Report of Tellers' Committee on
(a) Election of Officers; Introduction of and response from President-Elect
(b) Constitutional Amendments
Presentation of Prizes for Papers
Presidential Address, Harold B. Smith
12:30 p. m. Section and Branch Delegates' Luncheon
2:00 p. m. Officers' and Delegates' Conferences
Qualifying Round for Mershon Trophy
Tennis
Ladies' Drive to Granite Club
4:30 p. m. Afternoon Tea
9:00 p. m. President's Reception—dancing

TUESDAY, JUNE 24

9:00 a. m. Registration
9:30 a. m. Two Technical Sessions: (a) Protective Devices (Symposium on Transmission Line Relays III); (b) Transportation

2:00 p. m. Officers' and Delegates' Conferences—continued
Trips as scheduled
Sports as scheduled—First Round for Mershon Trophy
Ladies' Trip around Harbor
4:30 p. m. Afternoon Tea at Royal Canadian Yacht Club
7:00 p, m. Get-Together Dinner and Entertainment

WEDNESDAY, JUNE 25

9:30 a. m. Three Technical Sessions: (c) Automatic Stations; (d) Selected Subjects and Technical Committee Reports; (e) Transmission
11:00 a. m. Ladies' Trip to Mississauga Golf Club, where luncheon will be served
12:30 p. m. Directors' Luncheon and Meeting
2:00 p. m. Trips as scheduled
Sports as scheduled—Second Round for Mershon Trophy
Ladies' Golf and Bridge at Mississauga Golf Club
4-30 p. m. Afternoon Tea
7:00 p. m. Convention Banquet
8:15 p. m. Medal Presentation
9:30 p. m. Dancing—Cards

THURSDAY, JUNE 26

9:00 a. m. Boat leaves for trip to new Welland Canal
Lunch at St. Catharines
2:00 p. m. Inspection of Welland Canal
Trips to Queenston and Niagara Falls
Finals—Golf and Tennis
9:00 p. m. Dancing on boat

FRIDAY, JUNE 27

9:30 a. m. Two Technical Sessions: (f) Electrical Machinery and Transmission (Symposium on Coordination of Line, Station, and Apparatus Insulation); (g) Communication
12:30 p. m. Luncheon—Presentation of Prizes
2:00 p. m. Technical Session: (h) Electrical Machinery and Power Generation
Ladies' Trip to Old Mill—Golf
4:30 p. m. Afternoon Tea

TENTATIVE TECHNICAL PROGRAM

(Eastern Daylight Saving Time)

TUESDAY, JUNE 24

9:30 a. m. Parallel Sessions A and B

A. Protective Devices—Symposium on Transmission Line Relays III

The Problem of Service Security in Large Transmission Systems, Paul Ackerman, Consulting Electrical Engineer
Transmission Line Protection, H. P. Sleeper, Public Service Electric & Gas Co.
New Features in Relay Protection, O. C. Traver, General Electric Co.
New Directional Relay Schemes, E. E. George and R. H. Bennett, Tennessee Electric Power Co.
High-Speed Protective Relays, L. N. Crichton, Westinghouse Electric & Mfg. Co.

B. Transportation

Electric Power Consumption for Yard Switching, P. H. Hatch, N. Y., N. H. & H. R. R. Co.
Control Systems for Oil and Gasoline Electric Locomotives and Cars, N. L. Freeman, Westinghouse Electric & Mfg. Co.
Electric Transmission and Control of Power from Internal Combustion Engines for Transportation, S. T. Dodd, General Electric Co.
Auxiliaries for High-Voltage Direct-Current Multiple Unit Cars, C. J. Axtel, General Electric Co.
Summary of Experience of Various Railways with Rail Bonds, H. F. Brown, N. Y., N. H. & H. R. R. Co.
Auxiliary Circuits for High-Voltage D-C. Motor Car Equipments, O. K. Marti and W. A. Giger, American Brown Boveri Co., Inc.

WEDNESDAY, JUNE 25

9:30 a. m. Parallel Sessions C, D, and E

C. Automatic Stations

A Vacuum Tube Telemetering System, A. S. FitzGerald, General Electric Co.
Development of a Two-Wire Supervisory Control System with Remote Metering, R. J. Wensley and W. M. Donovan, Westinghouse Electric & Mfg. Co.
Centralized Control of System Operation, J. T. Lawson, Public Service Electric & Gas Co.
Automatic Power Supply of the Carnegie Steel Company, Robert Harry, Carnegie Steel Co.
1000-Kw. Automatic Mercury Arc Rectifier Substation of the Union Railway Company, New York, W. E. Gutzwiller and Otto Naef, American Brown Boveri Co.
Monowire Control for Automatic Substations, F. F. Ambuhl, Toronto Hydro-Electric System
Modernization of the Design of Operating Switchboards, Philip Sporn, American Gas & Electric Co.

D. Selected Subjects and Technical Committee Reports

Rural Life Construction in Ontario, R. E. Jones, Hydro-Electric Power Commission of Ontario
Mutual Impedance of Ground-Return Circuits—Some Experimental Studies, H. E. Bowen, American Telephone & Telegraph Co., and C. L. Gilkeson, National Electric Light Association
Theory and Characteristics of Grid-Controller Glow and Arc Discharge Tubes, D. D. Knowles and S. P. Sashoff, Westinghouse Electric & Mfg. Co.
Effects of the Magnetic Field on Lichtenberg Figures, C. E. Magnusson, University of Washington
A Survey of Room Noise in Telephone Location, W. J. Williams, National Electric Light Association, and R. G. McCurdy, American Telephone & Telegraph Co.

E. Transmission

The 220-000-Volt System of the Hydro-Electric Power Commission of Ontario, E. T. J. Brandon, Hydro-Electric Power Commission of Ontario
Steady-State Theory of Transmission Lines, T. R. Rosebrugh, University of Toronto
Study of the Effect of Short Lengths of Cables on Traveling Waves, K. B. McEachron, General Electric Co.; J. G. Hemstreet, Consumers Power Co., and H. P. Seelye, Detroit Edison Co.
Buried Distribution Type Transformers, C. E. Schwenger, Toronto Hydro-Electric System

FRIDAY, JUNE 27

9:30 a. m. Parallel Sessions F and G

F. Electrical Machinery and Transmission Symposium on Coordination of Line, Station, and Apparatus Insulation

Rationalization of Station Insulating Structures with Respect to Insulation of Transmission Lines, C. L. Fortescue, Westinghouse Electric & Mfg. Co.
Rationalization of Station Insulating Structures with Respect to Insulation of Transmission Lines, F. W. Peek, General Electric Co.
Rationaliztion of Transmission Line Insulation Strength, Philip Sporn, American Gas and Electric Co.

Recommendations on Balancing Transformer and Line Insulation on Basis of Impulse Voltage Strength, V. M. Montsinger, General Electric Co., and W. M. Dann, Westinghouse Electric & Mfg. Co.

Cordination of Insulation as a Design Problem, G. D. Floyd, Hydro-Electric Power Commission of Ontario

Standards of Insulation and Protection for Transformers, J. A. Johnson, Buffalo, Niagara and Eastern Power Corp., and E. S. Bundy, Niagara, Lockport & Ontario Power Co.

Essential Factors in the Coordination of Line, Station, and Apparatus Insulation, A. E. Silver and H. L. Melvin, Electric Bond and Share Co.

G. Communication

Long Distance Cable Circuit for Program Transmission, A. B. Clark, American Telephone & Telegraph Co., and C. W. Green, Bell Telephone Laboratories, Inc.

Transmission Characteristics of Open Wire Telephone Lines, E. I. Green, American Telephone & Telegraph Co.

Study of Telephone Line Insulators, L. T. Wilson, American Telephone & Telegraph Co.

General Switching Plan for Telephone Toll Service, H. S. Osborne, American Telephone & Telegraph Co.

Long Telephone Lines in Canada, J. L. Clarke, Bell Telephone Company of Canada

Two-Way Television, H. E. Ives, Bell Telephone Laboratories, Inc.

2:00 p. m. Session H

H. Electrical Machinery and Power Generation

Effects of Lightning Voltages on Rotating Machines and Methods of Protecting against Them, F. D. Fielder and E. Beck, Westinghouse Electric & Mfg. Co.

Effect of Voltage Surges on Rotating Machinery, E. W. Boehne, General Electric Co.

Vertical Shaft 25,000 Kv-a. Synchronous Condensers, H. A. Ricker, J. R. Dunbar and R. E. Day, Canadian Westinghouse Co.

Metal-Clad, Gum-Filled Switching Equipment, L. B. Chubbuck, Canadian Westinghouse Co.

East River Generating Station of the New York Edison Company, C. B. Grady, W. H. Lawrence, and R. H. Tapscott, New York Edison Co.

Hydro Power Practise in Central Europe, A. V. Karpov, Aluminum Company of America

Trips

Welland Canal

The outstanding trip will be an all-day outing, crossing Lake Ontario to visit the new Welland Canal, which embraces some features excelling anything hitherto undertaken in canal construction. Those desiring to do so will be able to spend the afternoon at the Queenston Plant of the Hydro-Electric Power Commission or at various power plants at Niagara Falls. Special entertainment features are being arranged in connection with this trip in a way that will ensure a day of general relaxation and enjoyment.

Leaside Station

The Leaside Station of the Hydro-Electric Power Commission on the outskirts of Toronto is Canada's first 220-kv. receiving station. It has many interesting features, including two 25,000-kv-a. outdoor synchronous condensers.

Other Power Stations

H. E. P. C.—Bridgeman—110-kv. Station.
Wiltshire—110-kv. Station.
Strachan Ave—110-kv. Station and Laboratories.

Toronto Hydro-Electric System
Automatic High Power Mercury Arc Rectifier Railway Station.
Supervisory Control Substations.
Local Dispatching Office in Duncan Street Station.

Electric Manufacturing Plants

Davenport Works—Canadian General Electric Co.
Hamilton Works—Canadian Westinghouse Co.
Mount Dennis Plant—Ferranti Electric Limited.

Points of Interest

Hillcrest Shops—Toronto Transportation Commission.
Toronto Harbor Development.
University of Toronto Buildings.
Royal Ontario Museum.

There are also many manufacturing plants to which trips will be arranged as desired.

Sports

Golf

The main event for golfers will be the annual tournament for Mershon Trophy, which will be played over the course of the Weston Golf and Country Club.

As it is proposed to present the prizes at the luncheon on Friday, and as the match play in this competition will consume all other available time, it is essential that the qualifying round be completed on Monday. This will mean that guests arriving after Monday will be unable to enter the Mershon Cup competition.

> The competition will consist of a qualification round (handicap medal play) of eighteen holes, followed by match play (handicap).
>
> The sixteen low net scores will qualify for the match play rounds, which will be played on Tuesday p. m., Wednesday p. m., and Thursday, a. m. and p. m.
>
> Arrangements will be made by the Committee so that officers, section delegates, et. al., may play their qualification rounds at any particular time on Monday, so as to avoid missing their scheduled meetings.

The Committee are also arranging other events, the details of which will be given out at registration. These events will not be confined to the course of the Weston Golf & Country Club, as arrangements are being made to allow members and registered guests to play over a number of courses in the Toronto vicinity, and all scores will count in these competitions.

It is hoped that the chief among these additional events will be an International Team Competition for the American Canadian Team championship of the Institute, arrangements for which are now being worked out.

No greens fees will be charged members or registered guests for any play during the Convention, and transportation to and from all courses will be provided.

Tennis

The annual Mershon Trophy competition in Men's Singles will be played, together with Men's Doubles, and, if sufficient entries can be secured, Ladies' Singles and Mixed Doubles will also be arranged.

The courts on which these events will be played will be announced later, but tennis players can be assured that excellent courts (probably clay) will be available for all who wish to use them.

Entries for all these events should be in the hands of the Committee not later than Monday afternoon.

Entertainment

The principal entertainment features are shown in the foregoing program. It is expected that these events will be outstanding for their respective kinds. In general, the Committee is leaving no stone unturned in its efforts to make this Convention a memorable one.

Ladies

The ladies attending the Convention should have a particularly interesting time, as the Committee has arranged a very attractive program for their entertainment. In addition to the all day trip by boat across Lake Ontario, to view the Welland Canal, there will be two different drives covering points of interest in and about the city. An afternoon of golf has been arranged preceded by luncheon at the Mississauga Golf Club,—there will be a bridge game arranged for those not playing golf.

On another afternoon it has been planned to take the ladies for launch rides along the lake shore, in the vicinity of the harbor and have tea served afterwards at the Royal Canadian Yacht Club. There will be two dances during the Convention, in the evening.

A large local Committee of Ladies will do everything possible to look after the comfort and pleasure of visiting ladies, both individually and collectively.

Railroad Rates

It has been ascertained that in nearly all cases the Summer Tourist rates are lower than those offered by the Convention Certificate plan. On this account certificate rates are not being arranged and members are advised to procure Summer tourist tickets.

Committees

The 1930 Summer Convention Committee which is making arrangements for the convention consists of the following members who are officers of the General Convention Committee or chairmen of other committees as indicated or general members: C. E. Sisson, Chairman; A. H. Hull, Vice-Chairman; W. L. Amos, Secretary; A. E. Knowlton, Meetings and Papers; W. P. Dobson, Local Representative, Meetings and Papers; W. B. Kouwenhoven, Sections; W. A. Bucke, Finance; H. U. Hart, Finance; F. R. Ewart, Publicity; A. B. Cooper, Entertainment; H. C. Don Carlos, Sports; J. F. Neild, Transportation; M. B. Hastings, Trips; F. F. Ambuhl, Hotel and Registration; H. C. Barber, Ladies; W. C. Adams, C. V. Christie, J. L. Clarke, J. R. Cowley, E. P. Fetherstonhaugh; J. A. Johnston, H. Milliken, J. Morse, W. F. McKnight, J. Teasdale and J. B. Woodyatt.

Pacific Coast Convention

A splendid Convention, with varied engineering subjects and delightful entertainment, is being planned and will be held at Portland, Oregon, September 2-5. Headquarters will be at the Multnomah Hotel. Five technical sessions, two Student Branch sessions, and a conference on student activities by the Counselors' Committee from Districts Nos. 8 and 9 comprise the technical and business phases of the program.

Engineering Papers

A variety of practical, theoretical, and research papers fall into four general classifications: transmission and distribution, power station development, communication, and research. A few of the subjects are: forecasting precipitation; mercury arc rectifiers, corona tests, porcelain insulator research, and power company communication systems.

Entertainment and Trips

An informal reception and dance, the annual golf tournament for the J. B. Fisken cup, followed by an informal banquet at the Country Club, are the major entertainment features. Plans are being made to secure for the golf tournament, the course of the Portland Golf Club,—one of the finest among Portland's many excellent courses, while the ample facilities afforded by its new clubhouse will make an excellent setting for an informal banquet and dance on the evening of the tournament.

Instructive trips of diverse interest are being planned, among which a visit to the Oak Grove Development of the Pacific Northwest Public Service Company on the Clackmas River where a second generating unit is being installed; and another to the Northwestern Electric Company's hydroelectric development on the Lewis River where construction work on a dam in progress will be of major interest.

Delightful entertainment for the ladies,—luncheons, teas and bridge at some of the many beauty spots in and around Portland,—will be provided.

Members are urged to plan their vacations to include this convention. The Northwest is rapidly becoming a very popular summer playground area, and Portland is a convenient starting point.

Further details will appear in subsequent issues of the Journal.

The I. E. C. Plenary Meeting

The Plenary Meeting of the International Electrotechnical Commission, to be held June 27-July 9, at Copenhagen, Stockholm, and Oslo, will open officially at Copenhagen Friday, June 27, with the address of welcome. The afternoon will be devoted to inspection trips and an official dinner will be given in the evening by the Danish Electrotechnical Committee.

On the morning of June 28, the visitors will leave by special train for Helsingör stopping for a luncheon reception given by the Sydsvenska Kraftkatiebolaget (South Sweden Power Co., Ltd. an important operation in that it supplies most of the electric power to the south of Sweden). A visit will also be paid to its new water power plant of Karsefors, on the River Lagan. The installation of this plant has just been completed and a portion of the energy here produced is distributed to Denmark through 50,000-volt cables across the Oresund Straits. Other plants of interest will be visited enroute. Dinner will be served at Trollhättan by the Royal Board of Waterfalls. The Advisory Committees will start work Monday, June 30th, continuing through until the evening of July 5th with the exception of July 3d, when the delegates are invited to visit the Asea works in Västeras. After luncheon, on July 3d, the party will inspect the 87,000-kw. steam power plant used as a stand-by to the water power stations in the state electrification system.

Oslo will be reached the morning of July 6th, the train arriving at the Power Plant of Raanaasfoss, with opportunity to any wishing to do so, to complete the journey to Oslo by charabanc. The Rjukan installations, belonging to the Norwegian Hydro-Electric Nitrogen Company, and consisting of two stations of approximately 125,000 kw. capacity each, will be visited; other excursions will be to the Nore Power Plant and the Vamma Plant belonging to A/S Hafslund and situated on the River Glommen. The latter plant is used for the production of zinc and carbide as well as for electrical supply. At the close of the sessions, the Norwegian Electrotechnical Committee has arranged an excursion for its visitors to view the phenomenon of the midnight sun; the route will be over the Dovre Mountains to Trondhjem, thence by steamer along the coast to Troldfjord (Lofoten). If 100 persons register for this trip, a special steamer will be chartered, the inclusive cost being 325 Norwegian crowns (£18). By those who prefer it, the return journey to Oslo may be via Narvik, Kiruna, Porjus, Stockholm, including a visit to the Kiruna Mines and the Porjus Power Plant excavated in the rock 50 metre below the surface.

Technical sessions in Stockholm will include Nomenclature, Rating, Symbols, Hydraulic Turbines, Steam Turbines, Lamp Caps and Holders, Aluminum, (Voltages and High-Voltage Insulators), Electric Traction Equipment, Insulating Oils, Overhead Lines, Radio-communication, Measuring Instruments, Rating of Rivers, Shellac, Terminal Markings, Oil Switches, Ship Installations and Internal Combustion Engines.

A bureau of information will be opened in Copenhagen on June 25, but anyone in this country wishing further details should communicate with Mr. H. S. Osbrone, Secretary, 33 West 39th St., New York, N. Y.

World Power Conference at Berlin

The Second Plenary World Power Conference to be held in Berlin, June 16-25, will be inclusive of much valuable information to assist in solving some of the largest and most complex problems which are today confronting engineers. The program of papers will be divided into four classes as follows:

Class A—*Sources of Power:*—Solid Fuels; Gaseous Fuels; Water Power.
Class B—*Power Production; Power Transmission; Storage:*—Steam Power Plants and Fuels, Internal Combustion Engines, Water Power Plants and Electric Power Plants.
Class C—*Utilization of Power:*—Domestic Economy and Industry Transport; Power Utilization in Building Work and in Factories.
Class D—*General:*—Distribution of Power; Power and Legislation; Education; Standardization and Statistics; and General.

The 1930 Conference will promote study toward practical application, concentrating upon the distribution and utilization of power. It will examine the social implication of power and will study power generation and its use as a unifying force in the relationship of nations. The program will be planned for breadth of vision and diverse and compelling interest for all leading consulting engineers, designers, industrialists, professors in engineering and government experts.

Special events will be available. Oberammergau, the village in which the Passion Play is enacted every ten years, (and being given this year), is but a short distance by train or motor from Munich. A performance will take place on Sundays, Wednesday, and Holy days throughout the summer. It will not be given again until 1940. At the Bayreuth Festival, the Wagnerian operas will be given in Wagner's own theater through late July and August. Leipzig will also be the scene of unusual summer festivities.

The Conference papers will be read in three languages,—French, English, and German.

Inquiries concerning further detail should be addressed to O. C. Merrill, Chairman of the American Committee, Washington, D. C.

Automotive Engineers to Meet May 25-29

Plans for the celebration of the twenty-fifth anniversary of the Society of Automotive Engineers, to be held at French Lick Springs Hotel, French Lick, Indiana, May 25th to 29th, include a presentation of a number of historic motor cars and accessories, displays of early newspaper and magazine automotive advertising, and an exhibit of photographs and editorial accounts of outstanding automotive events which have occurred in the past 25 years.

More than 1200 automotive engineers and executives will be present, including many prominent officials who can claim association with the motor industry since the early nineties. Among the several hundred exhibits will be contributions loaned by the Smithsonian Institution including the Manly aeronautical engine; several models of early internal combustion engines; the famous "999" racer and other museum pieces loaned by Henry Ford; a number of round-the-world cars, old steam cars, cars of "ancient vintage" from such factories as Franklin, Hupmobile, Peerless, Oldsmobile, and many other well-known maker; the original motor, hand-built by Orville and Wilbur Wright and utilized in some of the very early flights; and other early inventions in this field of application.

Thirty French engineers representing the Societe des Ingenieurs de L'Automobile will be present; also a number of Government officials from the Department of Commerce and the Bureau of Standards, representatives of the Army and Navy, and the various automotive and aeronautical associations.

The A. S. M. E. Holds Fiftieth Anniversary

On April 9, The American Society of Mechanical Engineers brought to a successful close the five-day ceremonials of its fiftieth anniversary.

The celebration opened officially Saturday, April 5, with the unveiling of a tablet in the Main Foyer of the Engineering Societies Building, 33 West Thirty-Ninth Street, John Sweet, a grandnephew of John E. Sweet, founder and third president of the Society, performing this function. This tablet, designed by Julio Kilenyi, portrays the engineer in figure of Herculean physique, gazing far beyond a group of presently available instruments for scientific measurement into the unknown distance of the future, the inscription above him "What is not yet, may be" implying the unlimited scope to which the profession may yet extend man's horizon, while Doctor Durand, in his dinner address, contended that the engineering profession also extended back to the days of Prometheus who "brought down fire from Heaven and subdued it to the service of mankind." The commemorative exercises were continued in a program under the auspices of the McGraw-Hill Publishing Co., Inc., and a series of pageants enacted at Stevens Institute, portraying some of the various steps of progress initiated by the engineer into the many fields of development,—Watt's workshop, the first train over Chat Moss Bog, Faraday's experiments, and others down to the days of Mr. Edison's pioneer achievements.

On Monday the meeting adjourned to Washington, D. C. with headquarters at the Mayflower Hotel. The welcoming assembly, however, was held in the National Council Chamber of the United States Chamber of Commerce Building, a few blocks from headquarters. In the absence of President Charles Piez who is unfortunately ill, Ralph E. Flanders, a Vice-President of the Society, presided, and present on the platform with him were six other Vice-Presidents of the A. S. M. E. Mr. Flanders welcomed the delegates in the name of the Society, and then turned the meeting over to Secretary Calvin W. Rice, by whom were introduced the delegates of the various engineering organizations both domestic and foreign. Among these were representatives from Canada, Colombia, Norway, Denmark, Great Britain, Australia, Austria, Belgium, France, Germany, Switzerland, Turkey, the Netherlands, Mexico, Japan and Union of South Africa.

At this meeting also was inaugurated the Hoover Gold Medal, details of the first award of which, made to President Hoover, are given in article following.

The Fiftieth Anniversary celebration closed with a reception at the White House, where, in the Blue Room, over a thousand guests were welcomed and greeted individually by President and Mrs. Hoover.

President Hoover Receives First Hoover Gold Medal

To Hoover Gold Medal, instituted to commemorate the civic and humanitarian achievement of Herbert Hoover, and to be subsequently periodically awarded by the engineers "to a fellow engineer for distinguished public service," was, in its first award at the A. S. M. E. Anniversary Dinner on the evening of April 9, in Washington, D. C., bestowed upon President Hoover. The ballroom of the Mayflower Hotel, in which the dinner was served, was effectively decorated with a profusion of flags, flowers, and the A. S. M. E. emblem. The United States Marine Band supplied the music and President and Mrs. Hoover, escorted by the officers of the Society, were seated at a centrally located table. Doctor Durand, as toastmaster, introduced Doctor Millikan, who took for his subject "The History of Fire" and won from his audience the usual degree of enthusiasm. Dean Kimball then took the chair, calling upon J. V. W. Reynders, Past-President of the American Institute of Mining and Metallurgical Engineers, who gave a brief exposé of President Hoover's personal achievements in civic and humanitarian fields; he also outlined the detail of the founding of the Hoover Gold Medal, which, in its first presentation, would be bestowed upon President Hoover, himself. The trust fund by which this award is established was created by the gift of Conrad N. Lauer; it is to be

held by The American Society of Mechanical Engineers and administered through a Board of Award comprised of representatives of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers. President Hoover in his response to the award expressed his appreciation of this honor conferred upon him by the combined engineering societies, the beneficence of Mr. Lauer in establishing this new distinction among engineers, the application of the national tools developed by science, and the discoveries and inventions which had brought so much of blessing to mankind. "Every county government," he asserted, "every municipal government, every state government, and the Federal Government itself, is engaged in a constant attempt to solve the multitude of public relations which these tools which the engineers, by their genius and their industry, constantly force upon the very doorstep of the Government." He closed by saying, "I am not advocating that all public service be turned over to the engineers; I have a high appreciation of the contributions of the other professions; but the engineers, I do insist, have a contribution to make to public service, and they have obligations to give that contribution."

National Hydraulic Labaratory Bill Passes Congress

The National Hydraulic Laboratory Bill authorizing an appropriation of $350,000 for construction and installation on the present site of the Bureau of Standards, Washington, D. C., of a laboratory building with such equipment and appurtenances as may be necessary, has passed both the House and Senate. The bill as passed by the House contained two provisos not in the Senate bill: The first granted municipalities and state engineering agencies the privilege of consulting the laboratory; the second restricted the laboratory only to such tests concerning hydraulic projects under Federal agencies as were specifically requested by the heads of the departments concerned with the execution of these projects. The bill now goes to conference and it is anticipated that it will become a law within a few weeks.

The Montefiore Prize Awarded Messrs. Evans and Wagner

Recent announcement has been made that the U. S. 1929 Montefiore prize, which includes the sum of 3000 Belgian francs, was awarded R. D. Evans and C. F. Wagner,—both members of the Institute and engineers of the Westinghouse Electric and Manufacturing Company who have earned prominence in connection with their apparatus used to demonstrate the phenomena associated with transmission stability problems.

The prize was bestowed by the Montefiore Foundation, of Liege, Belgium, for the best original article presented during the three years preceding the award, contributing to the science of electricity. Other participants in the award were A. Marino of Rome, and H. Parodi and Pestarine of Paris.

American Engineering Council

COMMITTEE ON BRIDGE LEGISLATION SELECTED

Within recent years, the subject of bridges, especially toll bridges, has been extensively discussed by members of Congress. There are a number of bills now pending in Congress relating to this subject, and from the trend of affairs, it is evident that sooner or later Congress is going to enact additional bridge legislation.

Since this subject is peculiarly within the field of action of the engineering profession, Council has given consideration to it and has come to believe that the importance of the subject is such that it should form a special committee, composed of men versed in the matter, to study all bridge bills pending in Congress and to recommend to Council what action, if any, it should take with respect to them.

Because of the provision which gives Congress jurisdiction over navigable streams, permission to construct bridges must be granted by special congressional legislation. Bridges are in accordance with three or four general acts first passed upon by the Corps of Engineers, U. S. A. with recommendations to Congress as to the advisability of granting permission for construction. In nearly all cases these recommendations are followed. If the persistency of general legislation on this subject is used as a guide, there is evidently a considerable demand for simplification and codification of the present existing law.

Through its Board of Direction, The American Society of Civil Engineers has placed itself on record with respect to one phase of this question by a resolution reading in part as follows:

"That the American Engineering Council be advised that the Board of Direction of the American Society of Civil Engineers is definitely opposed to congressional action of any character imposing unreasonable limitations upon the financing, design, construction and maintenance of toll bridges either inter or intra state."

The American Institute of Consulting Engineers has taken a similar position and Council has supported the position of these two member organizations.

COLEMAN ACCEPTS MEMBERSHIP ON FLOOD CONTROL COMMITTEE

John F. Coleman, of New Orleans, President of the American Society of Civil Engineers, has recently accepted membership on Council's Committee on Flood Control. The Committee is now composed of Gardner S. Williams, Cornwell Building, Ann Arbor, Michigan, Chairman; Baxter L. Brown, consulting engineer, St. Louis, Mo.; John R. Freeman, Grosvenor Building, Providence, R. I.; Dr. Arthur E. Morgan, President, Antioch College, Yellow Springs, Ohio; John F. Stevens, Wyman Park Apartments, Baltimore, Md.; and John F. Coleman, New Orleans, La.

PUBLIC HEALTH BILL PASSES

President Hoover has signed the so-called "Public Health Bill," H. R. 8807, which provides for the coordination of the public health activities of the government. This bill was passed during President Coolidge's administration but was vetoed on the grounds that it limited the constitutional authority of the President to make appointments and that it gave military status to the officers and employees of the service engaged in scientific pursuits.

In the bill which passed, the cause for these objections has been eliminated. This bill has been of continual interest to the engineering profession because it places the sanitary engineers in the Public Health Service on a parity with members of the medical profession. Council has worked diligently for the enactment of this constructive legislation.

A COOPERATIVE COMMITTEE ON WHO'S WHO IN ENGINEERING

"To provide such advice on the qualifications of engineers as will enable the publishers to issue a work which shall be authoritative," Council has appointed a Committee to cooperate with the publishers in a new edition of Who's Who in Engineering.

The Committee represents membership in American Institute of Chemical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Agricultural Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Grand Rapids Engineers Club, Society of American Military Engineers, Society of Industrial Engineers, Taylor Society; it consists of R. F. Schuchardt, chief electrical engineer, Commonwealth Edison Company, Chicago; John S. Conway, Washington; Dr. Harry A. Curtis, Department of Chemical Engineering, Yale University; C. R. Dooley, Standard Oil Company, New York N. Y.; Colonel Frank M. Gunby, associate, Charles T. Main, Inc., Boston; Arthur Huntington, Iowa Railway and Light Corporation, Cedar Rapids, Iowa; B. A. Parks, Bryon E. Parks and Son, Grand Rapids, Mich.; Dr. H. S. Person, managing director, Taylor Society, New York City; Dean A. A. Potter, School of Engineering, Purdue University, Lafayette, Ind.; George S. Rice, chief mining engineer, U. S. Bureau of Mines, Washington; F. F. Sharpless, consulting engineer, New York City; Robert Sibley, executive manager, California Alumni Association, University of California; Major Brehon B. Somervell, district engineer, U. S. Engineer Corps, Washington.

COUNCIL COMMITTEE TO CONFER ON AERONAUTICS

A committee has been formed which will confer with the Aeronautics Branch of the Department of Commerce for the purpose of developing a plan whereby the Aeronautics Branch and American Engineering Council may cooperate in formulating a report for the general information and guidance of public bodies, indicating the diversity and importance of engineering problems in the design of airports.

The personnel of committee, which will be known as the Committee on Airports, is as follows: Chairman, Professor Ralph J. Fogg, Head of Civil Engineering Department, Lehigh University, Bethlehem, Pa.; Mr. Perry A. Fellows, City Engineer of Detroit, (also Chairman, Committee on Airports and Landing Fields, American Society of Municipal Improvements); W. W. Horner, Chief Engineer, Sewers & Paving of St. Louis, Missouri; Dr. Harrison E. Howe, Editor, Industrial and Engineering Chemistry, Washington, D. C.; Dr. Alexander Klemin, Head of Guggenheim School of Aeronautics, New York University; and H. G. Shirley, Commissioner of Highways, Richmond, Va.

CARL GRUNSKY IS HONORED BY CALIFORNIA CONGRESSIONAL DELEGATION

In recognition of the honors which have recently come to him, Carl E. Grunsky, distinguished Californian engineer, recently elected President of American Engineering Council and chosen to receive the Fiftieth Anniversary Medal of the American Society of Mechanical Engineers was entertained at an informal luncheon by the California Congressional Delegation.

Mr. Grunsky came to Washington, D. C., to participate in the Fiftieth Anniversary Celebration of the American Society of Mechanical Engineers at which he presented a monograph on Fifty Years Progress in Engineering in the United States.

Mississippi Flood Control Hearings

The hearings held February 10, 13 and 26, before the Flood Control Committee of the House of Representatives of which Frank R. Reid, of Illinois, is chairman, have now been printed and may be had from the Superintendent of Documents, Government Printing Office, Washington, D. C. This volume comprises 470 pages of testimony, presented by 37 men, many of whom were Congressmen and Senators from the states of the alluvial valley of the Mississippi River. The principal message which these men brought was that the project adopted in 1928 was not satisfactory, and that additional remedial legislation on this question was necessary.

The two principal projects presented to the committee was the one by Harry Jacobs, Chief State Engineer and President of the Board of State Engineers of Louisiana, the essential points of which provide not only for diversion of water from the Mississippi but storage in reservoirs. The other project considered by the committee was presented by A. B. B. Harris, Consulting Engineer of Richmond, Va. Mr. Harris contended that the location and design of the Bonnet Carre spillway is wrong from an engineering standpoint. He offered an alternate plan and location to the north of the proposed spillway, claiming for it a considerable economy.

The Corps of Engineers, U. S. A. was represented by Major Ernest Graves, member of the Mississippi River Commission and Lieut. J. P. Dean, Secretary to the Board of Engineers for Rivers and Harbors. These engineers stated that they had full knowledge of all the possibilities of the diversion as proposed by Mr. Harris, but had deliberately selected the Bonnet Carre site because it offered greater safety and protection to the city of New Orelans. It is known that in view of the almost universal condemnation of the Army Engineers' plans of 1928 by the engineering profession, and litigation produced by the present plans, Chief of Engineers General Lytle Brown is having a complete new study made of the Mississippi flood control situation and will render a report to President Hoover and Congress as soon as practicable.

A Scientific Advisory Board Appointed for the Westinghouse Research Laboratories

S. M. Kintner, Assistant Vice-President in charge of Engineering of the W. E. & M. Co. announces the appointment of a Scientific Advisory Board which will act in a consulting capacity to the personnel of the Westinghouse Research Laboratories. This is a part of the Research Expansion program as typified in the enlarged laboratories which by Fall will provide two and one-half times the present space facilities. The Advisory Board consists of the following scientists: Dr. C. E. Mendenhall, Head of the Dept. of Physics at the University of Wisconsin, Past-president of the American Physical Society and a member of the National Academy of Science; Dr. P. W. Bridgman, Professor of Physics at Harvard University, and member of various scientific societies including the National Academy of Science; Dr. Stephen Timoshenko, Head of the School of Advanced Mechanics at the University of Michigan and of international reputation; Dr. G. B. Waterhouse, Head of the Dept. of Metallurgy at the Massachusetts Institute of Technology; and Dr. Edward Mack, Jr., Head of the Dept. of Physical Chemistry at Ohio State University. This Advisory Board will meet as a group with the Section Leaders at the Research Laboratories approximately three times a year, and should provide an important link for closer cooperation between pure and applied science.

Commission on Public Domain Created

A bill, H. R. 6153, providing for a commission on Public Domain and authorizing an appropriation of $50,000 for the expenses of the commission, has passed both the House of Representatives and the Senate and will undoubtedly be signed by the President. Under the proposed law, governors of each of the eleven states, in which the 190,000,000 acres of public domain are now distributed, would each appoint a member of the commission, and the remaining members would be appointed by President Hoover. The purpose of the commission is to evolve a definite policy regarding public lands.

General Bridge Act Still in Committee

The General Bridge Act, H. R. 7879, proposed by Representative Denison of Illinois, for the purpose of regulating construction of bridges over navigable rivers and to revise the code of

laws governing consent of Congress to such construction, is pending consideration in the House Committee on Interstate and Foreign Commerce.

Motor Buss Bill Passes House

On March 24, the House of Representatives passed the General Motor Carrier Act of 1930, the purpose of which is to regulate transportation of persons in interstate and foreign commerce by motor carriers operating on the public highways. This is accomplished by placing motor carriers under the regulatory control of the Interstate Commerce Commission. The bill passed the House by vote of 219-115.

PERSONAL MENTION

Louis D. Fletcher, Patent Attorney with Darby & Darby, New York, has been made a member of the firm.

E. N. Willis, for many years Secretary o' The Southwestern Public Service Association, has accepted the position of Executive Secretary of the University Club of Dallas, Texas.

P. W. Sothman, having completed work on the Shannon Power Development, Irish Free State, Dublin, is now planning to carry on confidential work on reports, tests, investigations and negotiations in Alven, Holstein, Germany.

Ralph S. Kenrick, formerly Associate Editor of *Railway Age* and allied publications, has resigned to join the R. C. Nielson Company, (industrial marketing analysts), as an editor of engineering and marketing surveys.

P. K. Cramblett, previously Vice-President of the Time-O-Stat Controls Co., Elkhart, Indiana, has now organized the Cramblett Engineering Corporation of Milwaukee, Wisc., manufacturing sign flashers, electric heaters and mercury switches.

LeRoy S. Schell, effective April 1st was appointed Designing Engineer in charge of Transformer Engineering at the Erie Plant of the General Electric Co., being transferred from the Engineering Dept. of the Pittsfield Plant, where he has been for twelve years.

A. Strauss, on the 1st of March was called to organize the plant and production of the Dominion Electrical Mfg. Co., Minneapolis, Minn., manufacturing electric household appliances, a position which placed him at the head of the Technical Staff of that organization, acting as General Manager of the plant.

C. F. Hanson, who since 1927 has been engaged in development and sales of anti-oxidants for use in insulating oils and varnishes for the R. T. Vanderbilt Company, New York, N. Y., has now become Sales Engineer for the Irvington Varnish & Insulator Co., Irvington, New Jersey, where his duties will involve the technical development of varnished cambric and the sales and service of this material.

W. L. Abbott, chief operating engineer of the Commonwealth Edison Company, is one of the leading personalities in the organization of the new Chicago Bank of Commerce which opened April 12.

Mr. Abbott assumed the duties of Chief Engineer of the power house of the Chicago Edison Company in 1894, and five years later became chief operating engineer, a position he has filled every since.

R. E. Hellmund, Chief Electrical Engineer of the Westinghouse Electric and Manufacturing Company, has just been elected a member of the Board of Directors of the German Institute of Electrical Engineers. Thomas A. Edison is an honorary member of the same board. Notice of the award of the Lamme Medal to Mr. Hellmund appeared in the December issue of the Institute Journal.

W. S. Rugg, Vice-President of the Westinghouse Electric & Mfg. Co., due to the resignation of E. D. Kilburn, will take charge of the company's sales and engineering activities, with S. M. Kintner, Director of the Westinghouse Research Laboratories as Assistant Vice-President to assume engineering duties under his, Mr. Rugg's general direction. Mr. Kintner's work with the company has been the investigation of telephone interference and a-c. electrolysis.

Paul J. Kruesi, President of the Southern Ferro Alloys Company and a Past-President of the American Electrochemical Society, has been elected to the presidency of the American Lava Corporation, Chattanooga, Tennessee, of which he is one of the founders. Mr. Kruesi has been chosen by the Board of Directors to succeed his brother John Kruesi, deceased, whose services in this office were those of a far-sighted executive of wide acquaintance in the electrical industry and progressive management in his company.

Obituary

John J. Borger, Superintendent of Electrical Distribution for the Springfield Gas & Electric Company, Springfield, Missouri, and a member of the Institute since 1916, died April 9, 1930. He was born July 23, 1882, at Alexandria, Virginia, and received his education at the common schools in Florida and at the University of Florida, from which he was graduated with the class of 1901. From 1901 to 1904 he was engaged with the Florida Electric Company, Jacksonville, Florida, but left the employ of this company in 1905 to identify himself with the Public Service Electric Company of New Jersey, first as electrician and later becoming District Foreman. In 1906 he was made Chief Electrician in charge of the company's station in the Bergen Division, N. J., and then returned to the South to become Electrical Superintendent for the Augusta-Aiken Railway and Electric Corporation, Augusta, Ga., where his work was in designing, constructing and operating high-voltage lines and distribution systems, both overhead and underground. Mr. Borger had been with the Springfield interests for a number of years.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify Institute headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and assuring the prompt delivery of Institute mail, through the accuracy of our mailing records and the elimination of unnecessary expense for postage and clerical work.

Bakker, J. B., 440 Hyde St., San Francisco, Calif.
Birdsall, W. T., 6 Vincent Place, Montclair, N. J.
Brown, Garry E., 1280 Dean St., Brooklyn, N. Y.
Collinot, Marcel A., F. W. V. Rm. 1050, 11 W. 42nd St., New York.
DeCamp, H. H., 414 Ella St., Wilkinsburgh, Pa.
Degener, F. S., 1015 Casgrain Ave., Detroit, Mich.
De Salis, H. W., Box 66, Fort Frances, Ont., Can.
Duncan, W. C., 1121 Bedford Ave., Brooklyn, N. Y.
Fick, Ernest, A. T. & T. Co., 412 S. Market St., Chicago, Ill.
Fortin, R. P., Elec. & Gas Inspection Ser., 125 Prince William St., St. John, N. B., Can.
Gatternigg, R., Minarets, Calif.
Gioga, Peter, Metropolitan Sound Studios, 1040 N. Las Palmas, Hollywood, Calif.
Goldsborough, James, 50 Church St., Rm. 1272, New York.

Gorrissen, Chas., Hermannstrasse 38, Hamburg, Germany.
Hamrick, G. R., Sweetwater, Tex.
Hardey, John E., Nat'l. Electrical & Engg. Co., Ltd., Box 1055, Wellington, N. Z.
Hershey, H. E., Midwest Athletic Club, Madison St. & Hamlin Ave., Chicago, Ill.
Hyatt, C. Brown, Camac and Medary Sts., Philadelphia, Pa.
Irvine, H. B., 1 Union St., Schenectady, N. Y.
James, Edgar A., 912 S. Poplar St., Allentown, Pa.
Keegan, W. G., 767 Maple Ave., Los Angeles, Calif.
Kirkland, E. H., 6701 Cregier Ave., Chicago, Ill.
Klien, F. A., 1215 Locust St., Philadelphia, Pa.
Matthews, R. F., 123 Livingston St., Brooklyn, N. Y.
McDougall, D. J., 1501 W. Pierce St., Phoenix, Ariz.
Nims, F. D., 70 State St., Boston, Mass.
Noome, C., Catharijnesingel 33, Utrecht, Holland.
Patrick, R. A., 425 Granite St., Reno, Nev.
Quaas, Richard T., 545 W. 156 St., New York, N. Y.
Richman, S. L., 6823 McPherson Blvd., E. Pittsburgh, Pa.
Rivers, H. D., 298 Central Ave., Lynbrook, L. I., N. Y.
Sachse, A. O., 87 Court St., Newark, N. J.
Saliba, G. J., 311 86th St., Brooklyn, N. Y.
Schnug, Geo. J., 9 Garrison Ave., Jersey City, N. J.
Singer, R. H., 2214 Auburn Ave., Cincinnati, Ohio.
Slaboski, H. T., 1441 Main St., Northampton, Pa.
Smedberg, O. L., 916 12th St., Oregon City, Ore.
Stone, Walter, 4501 Malden St., Chicago, Ill.
Syed, Mustafa, 960 S. 9th St., Noblesville, Ind.
Tsatsaron, Nicholas, Central Restaurant, 300 W. 40th St., New York, N. Y.
Velasco, L. R., Apartado 8, Canargo, Cheh, Mex.
Voegli, R., Byllesby Eng. & Mngt. Corp., Pittsburgh, Pa.
Watts, W. E. G., General Delivery, San Francisco, Calif.
Wheeler, R. E., 345 W. 58th St., New York, N. Y.

A. I. E. E. Section Activities

NEW YORK SECTION COMMUNICATION GROUP TO MEET MAY 7

The last meeting of the Communication Group of the New York Section for the present administrative year will be held in the auditorium of the Bell Telephone Laboratories, 55 Bethune St. (corner of West St.) at 7.30 p. m. on Wednesday, May 7, 1930.

A diversified program has been arranged. The meeting will open with the presentation of three papers on phase distortion, as follows: *Phase Distortion in Telephone Apparatus* by C. E. Lane. In this paper the types of phase characteristics in telephone systems are treated, with an explanation of why telephone currents are distorted, and means for overcoming this distortion. The second paper by J. C. Steinberg entitled *Effects of Phase Distortion and Telephone Quality* will treat of the kinds of distortion occurring in telephone lines with its effect on speech transmission. H. Nyquist will present the third paper on *Measurement of Phase Distortion.* This paper has particular reference to measurements in field practise. A talking film prepared by Dr. H. Fletcher entitled *Telephone and Musical Quality* will then be shown. This film has recently been prepared to demonstrate the various factors affecting quality in telephone and musical reproduction. Lieutenant K. R. Cox of Chicago will then give a talk on "Application of Radio for Police Purposes." Lieutenant Cox has been largely instrumental in working out the practical application of radio for police purposes in Chicago and Detroit.

By courtesy of the Bell Laboratories the cafeteria will be open for those attending the meeting. Dinner will be served beginning at 6 p. m. at 75 cents per plate. A radio and musical program will also be available in the auditorium between 7 and 7.30 p. m., this will include Amos 'n' Andy.

POWER GROUP OF NEW YORK SECTION TO MEET MAY 13

The Power Group of the New York Section will hold its fourth and last meeting of the present administration year on Tuesday evening, May 13, 1930 at the Engineering Societies Building 33 West 39th Street, New York, N. Y. The meeting will start at 7.30 p. m. The subject will be "Prophesying Electrical Consumption." M. D. Hooven, Public Service Electric and Gas Co. and Chairman of the Load and Revenue Planning Committee of the N. E. L. A. will present the paper on forecasting loads. Several methods of prediction will be taken up and various factors entering into the problem described. There will be ample time for discussion.

COMMUNICATION GROUP TO ELECT OFFICERS

At the May 7 meeting of the Communication Group the following slate for officers of the Group for the year 1930-31 will be presented by the Nomination Committee for the approval of the membership.

Chairman—A. F. Dixon, Bell Telephone Laboratories
Vice-Chairman—F. H. Kroger, Radio Corporation
Secretary—I. S. Coggeshall, Western Union.

PUBLIC SPEAKING CLASS PLANNED BY NEW YORK SECTION

A public speaking class is being arranged by the Power Group of the New York Section to begin next Fall. Any member of the Section will be welcome to participate. Section members interested are asked to send in their names now. This will help the Committee to make adequate arrangements. Just send a brief note signifying your interest and complete particulars will be sent to you when final arrangements are made for the Fall. Address your letter to L. E. Frost, Chairman, Public Speaking Class Committee, New York Section A. I. E. E., 33 West 39th St., New York, N. Y.

FUTURE SECTION MEETINGS

Cincinnati

May 9, 1930—*Recent Developments in Railway Transportation*, by W. D. Bearce, Statistician of Transportation Engineering Department, General Electric Co.

May 22, 1930—Thesis work, by senior students, University of Cincinnati. Meeting to be held at Swift Hall, U. of C.

Cleveland

May 15, 1930—Annual Dinner Meeting. "*The Quest of the Unknown*," by Professor Harold B. Smith, President, A. I. E. E.

Detroit-Ann Arbor

May 20, 1930—*Electrical Developments in New York*, by T. F. Barton, District Engineer, General Electric Company, New York. Meeting to be held at State College, Lansing, Michigan.

Erie

May 20, 1930—*Television*, by J. O. Perrine, American Telephone & Telegraph Co., New York. Meeting to be held at the Mutual Telephone Co.

Pittsburgh

May 13, 1930—Annual Banquet and Ladies Night. Meeting and Dinner-Dance, Ball Room, Wm. Penn Hotel.

Seattle

May 20, 1930—Competitive Papers. A prize of $25. will be awarded by the Seattle Section to the member presenting the best original paper. Annual reports of Committees and officers. Election of officers for the year 1930-1931.

MEETING OF EXECUTIVE COMMITTEE OF SOUTH WEST DISTRICT

A meeting of the Executive Committee of District No. 7 was held at the University of Missouri, Columbia, on March 21, 1930, in connection with a District meeting of Student Branch representatives and the Tenth Annual Engineers' Week of the University, March 20-22. The student sessions included two during which 13 technical papers were presented and a conference on Student Activities. These are reported more fully in the Student Activities Department of this issue.

Three chairmen and four secretaries, representing four of the five Sections in District No. 7, attended the Executive Committee Meeting and also the Student Sessions. A considerable number of Branch representatives attended the Executive Committee Meeting and showed deep interest in the discussion of Section activities. Several of them expressed a desire to find opportunities to participate in Section work soon after graduation.

The following paragraphs indicate the principal subjects considered, and contain brief summaries of the remarks made in the presentations and in the discussions that followed:

Place of Sections in Civic Affairs,—G. H. Quermann, Chairman St. Louis Section. Section members should participate actively in the intense and diverse civic problems formed through the concentrations of population. Each Section should have a Civic Affairs Committee, composed of able and experienced members, in order that engineering assistance may be furnished to the community. A meeting devoted to topics of civic interest should be held occasionally, and the general public should be invited.

Development of the Interest of the Younger Members in Section Activities,—A. Chetham-Strode, Secretary Dallas Section. Younger men should be invited to present papers at one or more meetings per year held for this purpose. A symposium program on the developments in electrical engineering during the previous year is a good type. Some younger men should be appointed members of committees. All should be encouraged to value the acquaintanceships developed in Institute work. The Sections should invite members of neighboring Branches to attend meetings, and one or two joint meetings a year with the students in charge of the programs are helpful. The interest of the younger members will be roughly proportional to their participation in Section activities, and each should be given something to do.

Preferable Types of Programs for Section Meetings,—A. B. Covey, Chairman Kansas City Section. Programs should be adapted to the character of the membership and the average attendance. Civic problems should be considered in one or more programs each year. Illustrated addresses and demonstrations attract large attendance. Programs for the year should be varied, and should include papers by members of the Sections. Interchange of speakers with other local groups is desirable.

Building up Membership,—C. W. Mier, Chairman Oklahoma City Section. The activity of the Section membership committees is depended upon, to a large extent, to secure new members to replace those lost through death, resignation, and delinquency in the payment of dues. The membership committee must have a capable chairman and should contain representatives of the various groups. The proposed plan under which Enrolled Students would be admitted as Associates without payment of the entrance fee should be very helpful in building up the Institute membership. Notices of meetings sent to non-members may lead to a desire to join. Sections should make efforts to encourage delinquent members to retain their membership. An efficient reception committee should greet new members and visitors at each meeting, and it was suggested that the Section Chairman introduce the new members at each meeting.

Stimulating Attendance at Meetings,—B. D. Hull, Vice-President A. I. E. E. The responsibility for attendance at Section meetings rests primarily with the Meetings and Papers Committee and the Membership Committee. A record of the names of those attending meetings should be kept. A reception committee including in its membership several of the younger members could do effective work in greeting those attending the meetings and encouraging them to return for future programs. It is desirable that each Section have a Publicity Committee, or perhaps only a single representative, to induce local newspapers to publish announcements of meetings, and to supply a report to the newspapers after each meeting. Such information published by the papers would increase the attendance.

This plan of combining the annual meeting of the Section and Branch representatives with a program of university engineering functions provided very effectively for the necessary business and technical sessions and also for interesting events of other types. It was the general consensus of opinion that this type of meeting should be continued.

Registration for the A. I. E. E. sessions was 134, of whom 85 were visitors from other cities and schools.

PAST SECTION MEETINGS

Akron

G. E. Stolz, Westinghouse Electric & Mfg. Co. gave a talk on the selection of a motor as determined by the type of load. Two reel film followed, after which Mrs. Edna Holloway, Home Economist of the Northern Ohio Power & Light Co., demonstrated electric cooking, and W. T. Ackley, of the same company, gave a talk on domestic electric water heating equipment. Mrs. Holloway served sandwiches and coffee. March 14. Attendance 65.

Baltimore

Lightning from the Operator's Point of View,—Speakers: E. Hansson, Pennsylvania Water & Power Co.; H. C. Louis, Consolidated Gas Electric Light and Power Co.; J. L. D. Speer, C. & P. Telephone Co. Dinner preceded the meeting. March 21. Attendance 110.

Birmingham

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Vice-President W. S. Rodman gave a short talk on the aims and activities of the Institute. March 24. Attendance 50.

Chicago

Refined Heating, by Chester I. Hall, Hall Electric Heating Co. Election of officers for next term as follows: F. H. Lane, Chairman; F. R. Innes, Vice-Chairman; L. R. Mapes, Secretary-Treasurer. Joint meeting with the Western Society of Engineers. March 31. Attendance 400.

Cincinnati

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Illustrated.

Audible Light and Visible Sound, by John B. Taylor, General Electric Co. Demonstrated. February 17. Attendance 271.

G. C. Smith, Safety Director of the City of Cincinnati, described the present and proposed plans for the communication facilities of the city. Following Mr. Smith's talk the meeting was adjourned to reassemble in the display rooms of the American Laundry & Mfg. Co. where a complete line of equipment manufactured by this company was on display. March 13. Attendance 40.

Microchronics, by Joseph Slepian, Westinghouse Electric & Mfg. Co. Demonstrated. The meeting was preceded by a dinner at which William A. Chryst spoke on his recent trip to the Galapagos Islands with the Kettering party. Joint meeting with the Engineers Club of Dayton. April 8. Attendance 330.

Columbus

Radio Active Rays, by E. M. Hewlett, General Electric Co.;

Constitution and Transformation of the Elements, by Sir Ernest Rutherford, Scientist;

Oil Films on Water, by Irving Langmuir, General Electric Co. Film—"Conquering the Cascades." Joint meeting of all local engineering societies. March 28. Attendance 325.

Connecticut

The Development of High-Voltage Circuit Breakers, by E. B. Merriam, General Electric Co., and Vice-President District No 1, A. I. E. E.;

The following papers presented by students of Yale University:

The Development of Magnetic Circuits in Electrical Machinery, by F. H. Eastman and A. K. Wing;

The Condenser Excited Induction Generator, by S. E. Petrillo;

Single-Phase Loads from Polyphase Circuits, by R. B. Whittredge. Joint meeting with Yale University Student Branch, held in Dunham Laboratory, preceded by dinner. March 19. Attendance 50.

Dallas

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Professor Smith entertained at dinner prior to the meeting. February 24. Attendance 200.

The Future Trend of Illumination, by V. J. Graham, Edison Lamp Works;

Lamps, by J. H. McManemin, Edison Lamp Works;

Outdoor Illumination, by A. H. Bruning, Dallas Power & Light Co. March 17. Attendance 85.

Denver

Dinner and entertainment under the auspices of the ladies. Monte Carlo Whist played during the evening. March 13. Attendance 76.

Government Regulation of Radio Communication, by G. W. Earnhart, U. S. Assistant Radio Inspector. Meeting followed by a luncheon and inspection of the equipment and operation of KOA station. March 21. Attendance 96.

Detroit-Ann Arbor

The Electrical Industry in America, Paul S. Clapp, Managing Director, N. E. L. A. Dinner preceded meeting. March 18. Attendance 225.

Erie

Rayon, by Mr. Davidson, Viscose Co. of America. Three-reel film showing manufacturing processes presented. Dinner preceded meeting. March 11. Attendance 130.

Fort Wayne

Today's Research and Tomorrow's Engineering, by L. A. Hawkins, General Electric Co. March 20. Attendance 160.

Houston

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Illustrated with lantern slides. Joint meeting with the A. S. M. E., A. S. C. E., Houston Engineers Club, and A. I. A. February 25. Attendance 135.

Industrial Motor Control, by B. H. Berkeley, Westinghouse Elec. & Mfg. Co. Illustrated. March 11. Attendance 100.

Transmission Line Data, Wood Pole Construction, by Charles O. Pilgrim. Meeting preceded by dinner. March 25. Attendance 22.

Indianapolis-Lafayette

Steel Enclosed Mercury Arc Rectifiers and Their Transformers, by O. K. Marti, American Brown Boveri Co. Illustrated. January 15. Attendance 48.

Los Angeles

Annual joint meeting with the Student Branches of California Institute of Technology and University of Southern California. C. E. Fleager, Vice-President District No. 8, A. I. E. E., briefly outlined the aims and activities of the Institute. Talks by Professors Sorenson and Van Der Ley, after which the following papers were presented by Students:

The Applications of an Optical Oscillograph, by Karl Wolfe, Calif. Institute of Technology;

Single-Phase Condenser Motor, by Caino Hoover, California Institute of Technology;

X-Rays and Some Applications, by Sidney Rosen, University of Southern California. March 11. Attendance 170.

Louisville

Recent Applications of the Photoelectric Cell, by C. O. Bickelhaupt, Vice-President, Southern Bell Telephone and Telegraph Co. Illustrated. April 8. Attendance 125.

Madison

Taking the Guess Out of System Protection, by William C. Hahn, General Electric Co. March 12. Attendance 55.

Making Light Audible and Sound Visible, by John B. Taylor, General Electric Co. April 4. Attendance 375.

Mexico

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. March 7. Attendance 71.

Milwaukee

Growth and Character of Electric Service, by F. A. Coffin;

The Lakeside Power Plant and Proposed New Power Plant at Port Washington, by F. Dornbrook;

Power Distribution Systems and Ties Between Power and Substations, by W. E. Gundlach;

Rapid Transit Lines and Proposed Improvements, by E. J. Archambault;

Types, Design, and Construction of Cars and Busses for Local and Interurban Service, by J. H. Lucas. All of the above speakers from the Milwaukee Electric Railway and Light Co. Joint meeting with the Engineers Society of Milwaukee March 19. Attendance 350.

Ether Waves and What They Tell Us, by Reverend Poetker, Professor of Physics, Marquette University. April 2. Attendance 110.

Minnesota

Deion Circuit Breaker Developments and How They Affect System Stability, by A. C. Monteith, Westinghouse Elec. & Mfg. Co. Illustrated with slides. March 26. Attendance 78.

Audible Light, by John B. Taylor, General Electric Co. Demonstrated. April 2. Attendance 500.

North Carolina

A-C. Arc Interruption, by Joseph Slepian, Westinghouse Electric & Mfg. Co. Illustrated with slides.

Deion Grid Oil Circuit Breaker, by J. B. MacNeill, Westinghouse Elec. & Mfg. Co., delivered by H. G. McDonald of the same company. Illustrated.

Institute Activities, by Professor W. S. Rodman, Vice-President District No. 4, A. I. E. E. Dinner followed, after which *The Quest of the Unknown*, was presented by Professor Harold B. Smith, President, A. I. E. E. Meeting held at Raleigh, N. C. March 26. Attendance 150.

Inspection trip to Duke University at Durham, N. C. March 27. Attendance 40.

Pittsburgh

Guests of the Bell Telephone Co. of Pa. at a lecture and demonstration by Sergius P. Grace, Assistant Vice-President, Bell Telephone Laboratories, Inc., entitled, *Wonders of Sound Transmission*. March 18. Attendance 1800.

Portland

Electrical Engineering of Sound Picture Systems, by R. E. Crouch, Electrical Research Products, Inc. Sound pictures demonstrated. March 11. Attendance 80.

Rochester

Centralized Radio, by E. Jay Quinby, Victor Radio Co. Joint meeting with the Institute of Radio Engineers and Rochester Engineering Society. Dinner preceded meeting. March 28. Attendance 57.

St. Louis

Symposium on Developments during 1929, as follows:

Industrial Developments, by B. F. Thomas, Consulting Engineer;

Communication Developments, by John Casey, Southwestern Bell Telephone Co.

Generation, by E. L. Hough, Union Electric Light & Power Co.;

Transmission, by Stanley Stokes, Union Electric Light & Power Co. March 19. Attendance 65.

San Francisco

Developments in Communication During the Last Twenty-Five Years, by C. E. Fleager, Vice-President, Pacific Telephone & Telegraph Co. and Vice-President, District No. 8, A. I. E. E.;

Developments in the Electric Power Field During the Last Twenty-five Years, by J. P. Jollyman, Pacific Gas & Electric Co. Quarter-Century celebration meeting, preceded by dinner December 20. Attendance 135.

Switchgear Development Achievements, by A. W. Copley, Westinghouse Electric & Mfg. Co. January 31. Attendance 120.

Electricity in California Farming, by Ben D. Moses, University of California. February 28. Attendance 60.

Some Observations of a Recent Trip Around the World, by Warren H. McBryde. Illustrated with slides. Joint meeting with the A. S. M. E. Dinner preceded the meeting. March 27.

Saskatchewan

Einstein Theory, by R. N. Blackburn. December 21.

Factors Determing the Cost of Supplying Power to the Different Classes of Consumers, by E. W. Bull. February 21.

Development and Working of Synchronized Sound and Scene, by A. R. Varcoe. March 21.

Schenectady

Symposium on Aviation, as follows:

The Development of Aviation in New York State, by J. Griswold Webb, State Aviation Commission;

Electricity in Aviation; Aeronautical Instrument Equipments, by C. F. Green, General Electric Co.;

Radio Apparatus, by E. M. Kinney, General Electric Co.;

Airport Lighting, by H. C. Ritchie, General Electric Co. March 21. Attendance 160.

Seattle

The Electrification of the Lumbering Industry, by A. H. Onstad, Weyerhaeuser Timber Co. February 18. Attendance 108.

The Shuffleton Steam Plant, by W. K. Sanders, Stone & Webster. Illustrated with slides. Joint meeting of the local sections of the Founder Societies. March 18. Attendance 187.

Sharon

What Are You Afraid Of?, by Charles M. Newcomb. Banquet meeting. December 3. Attendance 275.

Photoelectric and Glow Discharge Devices and Their Applications to Industry, by H. B. Stevens, Westinghouse Elec. & Mfg. Co. Film—"Through the Oil Fields of Mexico." February 11. Attendance 180.

Recent Research Developments, by Thomas Spooner, Westinghouse Electric & Mfg. Co. Illustrated. March 4. Attendance 120.

Welding, by R. P. Tarbell, Lincoln Electric Co. and A. M. Candy, Westinghouse Elec. & Mfg. Co. Illustrated by moving pictures and slides. April 1. Attendance 210.

Southern Virginia

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E.;

The Organization and Work of the Institute, by Professor W. S. Rodman, Vice-President District No. 4, A. I. E. E. Meeting preceded by a dinner. March 28. Attendance 115.

Springfield

Practical Application of the Photoelectric Cell and Other Light Sensitive Devices, by S. M. Kintner and Phillips Thomas, both of the Westinghouse Elec. & Mfg. Co. Demonstrated. March 11. Attendance 300.

Toledo

Television, by W. C. Johnson, Ohio Bell Telephone Co. Illustrated with lantern slides. March 14. Attendance 105.

Heavy Duty Mercury Arc Rectifiers, by A. J. Marti, American Brown Boveri Electric Co. Illustrated. April 4. Attendance 70.

Toronto

Power Arc Follow-Ups, by W. K. Detlor, Bell Telephone Co. of Canada. Demonstrated. March 14. Attendance 94.

Electron, by Professor D. C. Rose. March 29. Attendance 101.

Utah

Photoelectric Experiments, by H. T. Plumb, General Electric Co. Following this address there was an inspection of the electrical laboratories of the University of Utah. Joint meeting of all local Sections and Student Branches of the National Engineering Societies to inaugurate Engineers Day. March 20. Attendance 250.

Vancouver

The Electric Trolley Omnibus, by Prof. E. G. Cullwick, University of British Columbia. January 22. Attendance 20.

Annual Students' Night at which the following papers were presented by students of the University of British Columbia:

The Grid System in Great Britain, by Mr. McKeever;

Bridge Measurements, by Mr. Harrower;

Hydroplane Hulls, by Mr. Abernethy. March 6. Attendance 47.

Modern Methods of Surveying, by N. C. Stewart, B. C. Dept. of Lands. April 2. Attendance 54.

A. I. E. E. Student Activities

JOINT SECTION AND BRANCH MEETING IN CLEVELAND

The annual joint meeting of the Cleveland Section and the Case School of Applied Science Branch was held at the School on March 20, 1930.

An address of welcome was given by R. B. McIntosh, Chairman of the Branch, and Professor T. D. Owens, Chairman of the Section, responded. After giving a summary of the activities of the Branch during the current year, Mr. McIntosh presided during the presentation of the following program:

A Handful of Power, by L. A. Amtsberg, Student.

E. C. Stone, Vice-President, A. I. E. E., District No. 2, gave an address upon the purposes and activities of the Institute.

New Developments in Radio Tubes, by H. L. Brouse, Student.

Discipline or Discipleship?, by Dr. William E. Wickenden, President of Case School of Applied Science.

In his address Mr. Stone pointed out one of the most important branches of Institute work is the work and growth of students. An opportunity is given early in the career of a student to take part in developing public relations and further opportunity is afforded through Student Branches as for example: attending the meetings, developing public speaking, the writing of clear, terse reports, two great essentials for engineering success over and above the technical knowledge one may possess. Meetings give opportunity to know the men in the industry and to get their points of view, to make the student himself more effective and assist in finding the place in life for which he is best fitted.

Dr. Wickenden reviewed the development of the engineering profession and education, and explained the problems of the modern college of engineering.

At the conclusion of the program, the electrical engineering laboratories were open for inspection. The attendance was 156.

Preparations for the meeting were made under the supervision of the committee chairmen: Inspection, J. S. Hudson; Campus Floodlighting, J. G. Rosswog; Publicity, V. S. Roddy; Hospitality, C. W. Lytton; Executive, R. B. McIntosh.

STUDENT BRANCH CONFERENCE AND CONVENTION IN SOUTH WEST DISTRICT

A very interesting and beneficial type of meeting was held at the University of Missouri, Columbia, March 20-22, 1930, when sessions of the representatives of the Sections and Branches in District No. 7 were combined with the program of the Tenth Annual Engineers' Week of the University.

After an address of welcome on Friday morning, by Dean E. J. McCaustland of the School of Engineering, a meeting of the District Executive Committee was held (See Section Activities Dept.). Student technical sessions were held Friday afternoon and Saturday morning, and Saturday afternoon was devoted to a Conference on Student Activities.

Other events to which the Section and Branch representatives were invited were: a barbecue Thursday evening, tea and open house Friday afternoon, knighting ceremony and laboratory

demonstrations Friday evening, and banquet and Saint Pat's Ball Saturday evening.

Technical Sessions

The papers named below were presented in competition for a handsome trophy offered by the Kansas City Section:

Friday Afternoon, March 21

Field Form of Alternators, W. C. Robinson, G. Steltzlen, and C. C. Treece, University of Arkansas. (Presented by Mr. Robinson).

Electrical Control of Photo Finishing, L. C. Pasley, Kansas State College.

A Magnetic Test for Welds in Steel, R. R. Miner, University of Kansas.

The Automatic Reclosing Circuit Breaker, Claude J. Grim, Missouri School of Mines.

Solution of Polyphase Systems, Jack M. Manley, University of Missouri.

Methods of Measuring Corona Losses, David Mitchell, University of New Mexico.

Saturday Morning, March 22

Practical Problems Encountered in Talking Picture Sound Reproduction, Eldon Peek, Oklahoma A. & M. College.

Telephonic Transmission Line Phenomena, Earl L. Hassler, University of Oklahoma.

Recent Developments in Street Railway Equipment, Willard J. Cox, Southern Methodist University. (Presented by B. J. Beaird).

The Voltage Doubling Rectifier, P. M. Honnell, Texas A. & M. College.

A Study of the Voltage to the Common Point of a Three Phase Y System, Lucien La Coste, University of Texas. (Presented by E. W. Toepperwein).

The Photoelectric Reflectometer, Clarence J. Kettler, Washington University.

In the judging of the papers, the written contents were given a weight of 60 per cent and were graded by all Counselors present. Presentation, with a weight of 40 per cent, was judged by all members of the District Executive Committee present, and the final decision was made by a committee of five, four of whom were members of the Executive Committee. The trophy was awarded to the Oklahoma A. & M. College Branch for the paper presented by Eldon Peek. L. C. Pasley and C. J. Kettler received honorable mention. Vice-President B. D. Hull announced the decisions of the judges and presented the trophy to Mr. Peek at the close of the Saturday morning session. The recipient responded briefly, stating his appreciation of the award, and his high opinion of the entire meeting.

Conference on Student Activities

At the Conference on Student Activities, held on Saturday afternoon, all of the 13 Branches in the District were represented by their chairmen or alternates, and all except one were represented by their Counselors also.

Dean George C. Shaad, Chairman of the District Committee on Student Activities, presided, and the student representative of each Branch was called upon to present a report on its activities during the present year. Considerable emphasis was placed upon the desirability of participation in the programs by students, and a number of the speakers reported that motion pictures have not, in general, been satisfactory to their members. The reports indicated that serious thought is being devoted to methods of improving the meetings, and that good progress is being made by many of the Branches.

A vote of thanks was extended to the faculty members and students of the University of Missouri for their contributions to the success and pleasure of the entire meeting.

At a previous meeting of the Counselors, Professor M. P. Weinbach, Counselor of the University of Missouri Branch, was elected Chairman of the District Committee on Student Activities for the administrative year beginning August 1, 1930, and was chosen to represent the Committee at the Summer Convention to be held in Toronto, June 23-27, 1930.

The registration at the meeting was 134, of whom 85 were visitors to the University of Missouri.

PAST BRANCH MEETINGS

Alabama Polytechnic Institute

Smoker. March 27. Attendance 40.

Debates as follows: Resolved: *That Co-eds should Share Date Expenses*, by T. N. Pyke, Student;

Resolved: That All Chain Stores Should be Abolished, by H. W. Overton and W. L. Cochrane, Students. April 13. Attendance 33.

University of Arizona

Election of officers as follows: Jack W. Newman, Vice-Chairman; W. T. Brinton, Secretary; C. J. Sabin, Treasurer. February 14. Attendance 13.

Life of Steinmetz, by Wenzel Fraps, Student. February 21. Attendance 13.

Life of Lamme, by Frank J. Rietz, Student. February 28. Attendance 13.

Life of Michael Faraday, by Weldon T. Brinton, Student. March 7. Attendance 12.

University of Arkansas

Operation and Maintenance of Storage Batteries, by R. G. Whipple, Electric Storage Battery Co.;

Communication, by B. D. Hull, Vice-President District No. 7, A. I. E. E;

Carpenter Dam Hydroelectric Development, by C. S. Lynch, Kansas Power & Light Co.;

Design and Operation of Transformers, by M. F. Mitschrich, Moloney Electric Co. March 25. Attendance 75.

Talks by students on the various trips the juniors and seniors are required to make. Joint meeting with the A. S. C. E. and A. S. M. E. April 3. Attendance 40.

Brooklyn Polytechnic Institute

Four-day inspection trip to the following plants: General Electric Co., Pittsfield, Mass.; General Electric Co., Schenectady, N. Y.; American Locomotive Works, Schenectady, N. Y.; and the Cohoes Hydroelectric Development. March 25-29. Attendance 30.

The following papers presented by students:

Description of Riverhead, L. I., Receiving Station of the R. C. A. for Long Distance, by H. Hutchinson;

Grid Control of Arc Discharge, by F. Campbell;

Beats—Audible and Inaudible, by A. Nagy;

Core Losses at Low Temperatures, by W. LaPierre. April 9. Attendance 37.

Bucknell University

Election of officers as follows: O. R. Sterling, Chairman; P. Hort, Secretary-Treasurer. April 9. Attendance 11.

University of California

Inspection trip to Television Laboratories, Inc. where a demonstration and explanation of the Farnsworth System of television was presented. February 22. Attendance 45.

Why Study Corrosion?, by Carlton E. Cherry, Student. Illustrated.

The Water Supply of the East Bay Municipal Utility District, by F. W. Hanna, East Bay Municipal Utility District. Refreshments. February 27. Attendance 28.

Problems in Tractor Construction, by Daniel Penkoff, Student;

Mechanics of Dams, by W. A. Perkins, Chief Dam Inspector for State of Calif. Joint meeting with A. S. M. E. Branch. March 26. Attendance 17.

Applications of Vacuum Tubes in Industry, by L. F. Fuller, Chairman San Francisco Section, A. I. E. E., and Executive Vice-President Federal Telegraph Co. Illustrated. April 2. Attendance 48.

Carnegie Institute of Technology

Transmission Networks of the Duquesne Light Co., by J. R. Britton, Student. Election of officers for next term as follows: M. W. Smedberg, Chairman; T. E. Zima, Vice-Chairman; G. H. Ikola, Secretary; R. W. Carter, Treasurer. April 2. Attendance 26.

Catholic University of America

Problems of Telephone Communication, by Thomas J. Dunn, Student. February 15. Attendance 15.

University of Cincinnati

The Panel Dial Telephone System and its Application to Cincinnati Conditions, by O. F. Schlemmer, Cincinnati & Suburban Bell Telephone Co. Inspection trip to the Melrose-Jefferson Exchange was preceded by this address. Refreshments. March 20. Attendance 60.

Clarkson College of Technology

Spot Welding, by S. H. Smith, Student;

The G. E. Brush Shifting Commutating Type A. C. Motor, by P. W. Rohrberg, Student;

Meter Testing, by G. B. Wing, Student. March 18. Attendance 20.

The Westinghouse Portable Oscillograph, by T. E. Simpkins, Student;

Power Factor Correction, by J. C. Meier, Student;

Airport Illumination, by R. J. Carter, Student;

Airway Illumination, by L. M. Byrnes, Student. April 1. Attendance 18.

Clemson Agricultural College

Life of Lamme, by C. V. Rentz, Student;

Development of the Commutator, by W. D. Craig, Student;

Current Events, by W. C. Wilburn, Student;

Transformer Developments, by G. W. Sackman, Student. April 10. Attendance 36.

University of Colorado

The History of George Westinghouse, by W. S. Trudgian, Westinghouse Electric & Mfg. Co. He also explained the slides entitled "The Pioneer." Film—"Westinghouse Steam Turbine." April 2. Attendance 104.

Cooper Union

History, Principles, and Operations of the Telautograph, by Mr. Wolgemuth, Student. March 5. Attendance 38.

University of Detroit

Telephone Facilities used for Radio Broadcasting Purposes, by Harold E. Taylor, Michigan Bell Telephone Co. Film—"Auxiliary Products of Telephone Research." April 3. Attendance 150.

Drexel Institute

The Development, Design, and Application of the Gas Electric Drive to the Automotive Vehicle, by L. M. S. Cooper, Philadelphia Rapid Transit Co. Illustrated. March 10. Attendance 43.

A. D. Molinaro, Student, gave a résumé of the recent Student Convention held at Lehigh University. *Mercury Arc Rectifier*, by Paul P. Molar, Student. April 3. Attendance 25.

Duke University

The Development of the Radio Broadcast Receiver, by Tony de Bruyne, Student;

Power Facts, by S. C. Plyler, Student;

The Romance of Radio, by N. B. Underwood, Student. March 18. Attendance 15.

Thirteen student members attended the North Carolina Section meeting held in Raleigh at which Professor Harold B. Smith, President, A. I. E. E., delivered his address, *The Quest of the Unknown.* Inspection trips as follows: State Prison, Bell Telephone Company, and Station WPTF March 26. Attendance 15.

University of Florida

The Distribution System of Tampa, Fla., by Wayne Warfield, Tampa Electric Co. Slides. Two-reel film on transformers. March 24. Attendance 55.

Film—"Wizardry of Wireless." March 25. Attendance 30.

Motion pictures. April 7. Attendance 45.

University of Idaho

Banquet at which five students gave talks as follows:

Testing of Meters by the Photoelectric Cell Method, by Donald Russel;

Uses of Electric Control Equipment in the Lumber Industry, by Redmond Pangborn;

Fred Dicus and Donald Wiseman gave readings;

Problems Confronting the Electrical Engineer in the Transmission of Power, by E. Hatch. February 27. Attendance 29.

Iowa State College

Audible Light and Visible Sound, by John B. Taylor, General Electric Co. March 31. Attendance 160.

University of Iowa

Conowingo Dam, by J. A. Heaty, Student. Film—"The Benefactor." January 22. Attendance 34.

Power Arc, by Mr. Bathe and Mr. Shad, Bell Telephone Labs., Inc., February 5. Attendance 60.

Insulation on High-Tension Lines, by J. R. Lindemann, Student;

Developments in Electrical Industry During 1929, by F. D. Lydelon, Student. February 12. Attendance 33.

Film—"Hydroelectric Power Production in the New South." February 19. Attendance 53.

Lightning Problems on Transmission Lines, by K. S. Plucas, Student;

Aurora Borealis, by E. E. Postel, Student. February 26. Attendance 29.

Work and Opportunity in the Bell System, by E. T. Findersen, Illinois Bell Telephone Co. March 5. Attendance 75.

Forest Rangers Defy Lightning, by H. Krouth, Student. March 12. Attendance 22.

Kansas State College

The Induction Regulator, by C. D. Backer, Student;

Television, by H. Klotzbach, Student;

Current Events, by E. C. Glasco, Student. Film—"Arc Welding." (Afternoon session). March 6. Attendance 74.

Current Events, by Mr. Graham, Student;

Relieving Salina of High Water Disturbances, by Mr. Karr, Student;

Measurement of the Intensity of Ultra-Violet Light, by Mr. Randle, Student. Film—"Lincoln Arc Welder. (Evening session). March 6.

Technical talks by two seniors. *Current Events*, by J. H. Linscott, Student. (Afternoon session). March 20.

University of Kansas

Equipping a General Automobile Repair Shop, by Robert Meyer, Student. General discussion of Branch affairs. March 13. Attendance 55.

Principles of Speech, by Edward Fisher, Student. Robert McDowell, Student, gave a report of the social events of the meeting of the 7th District held at Columbia, Mo. Kenneth Hentzen, Branch Chairman, gave a report of the present trend of Student meetings and explained new ideas that were discussed at that meeting. April 3. Attendance 47.

University of Kentucky

The following talks presented by Students:

Deion Circuit Breaker, by J. N. Gillham;

Oil Electric Cars, by M. W. Davis;

Uses of Electrical Eye, by J. C. Benson;

Electro-Cardiagraph, by E. W. Pentz. March 12. Attendance 43.

Lafayette College

Operational Calculus and How it Simplifies Electrical Calculations, by Dr. Byrd. March 4. Attendance 106.

Lewis Institute

Film —"Hydroelectric Power." Joint meeting with the Western Society of Engineers Branch. March 14. Attendance 72.

Lee DeForest gave a talk on his early associations with Lewis Institute and an explanation of experiments which led to the discovery of the Three-Element Vacuum Tube. Joint meeting with the Western Society of Engineers Branch. March 19. Attendance 550.

Recent Discoveries in the General Electric Laboratories, by J. F. Sanborn, General Electric Co. Slides. Joint meeting with the W. S. E. Branch. April 11. Attendance 62.

Louisiana State University

Discussion of Branch activities. March 13. Attendance 19.

Professor W. S. Rodman, Vice-President, District No. 4, A. I. E. E., visited the Branch and gave an account of the early history of the A. I. E. E. April 10. Attendance 17.

University of Louisville

High-Frequency Quartz Crystal Oscillators, by Edward Knoop, Student;

Ampere-Voltmeter Measurements and K. V. A. Method, by Charles I. Brody, Student;

Recording Torque Indicator, by Andrew Offutt, Student. January 16. Attendance 19.

Mercury Arc Rectifiers, by Wm. F. Steers, Chairman, University of Kentucky Branch;

Outline of the Manner in Which the Speed School is Operated, by H. T. Clark, Chairman, University of Louisville Branch. Short talks by Professor Harold B. Smith, President of the Institute, Professor W. E. Freeman, and Professor W. S. Rodman. February 18. Attendance 52.

Marquette University

Essential Non-Essentials, by Mr. Armfeild, Wisconsin Bell Tel. Co. Business meeting followed. April 3. Attendance 34.

University of Michigan

Business meeting. March 13. Attendance 35.

Banquet. Professor J. S. Morley spoke on pioneering engineering and discussed many early modes of transportation. Illustrated with lantern slides. *The Lost Century in American History*, by Professor A. S. Aiton. April 7. Attendance 40.

Mississippi A. & M. College

Professor W. S. Rodman, Vice-President District No. 4, A. I. E. E., gave an address on the history, development, and future of the Institute. March 18. Attendance 44.

Montana State College

Practical Uses of Thermocouples, by Vincent Morgan, Student;

Cathode Ray Television, by V. Zworykin, Westinghouse Electric & Mfg. Co., presented by J. H. Radcliffe, Student;

A Curious Phenomenon in Vacuum Tubes, by W. S. Andrews, presented by Bruce Mull, Student. March 6. Attendance 155.

Dance. March 7. Attendance 120.

The Relation of the Bell System to its Component Companies, by R. B. Bonney, Mountain States Tel. & Tel. Co. March 11. Attendance 218.

University of Nebraska

Talks by three students who acted as consulting engineers trying to sell their services to a town board that was in need of a power plant. Other students acting as the board decided on the merits of the salesmen. March 19. Attendance 30.

Audible Light and Visible Sound, by John B. Taylor, General Electric Co. Demonstrated. March 28. Attendance 250.

University of Nevada

W. C. Smith, General Electric Co., gave a talk on transformers. Illustrated with motion pictures. January 22. Attendance 43.

P. B. Garrett, Westinghouse Electric & Mfg. Co., gave a talk on new developments in the electrical industry. Illustrated. February 20. Attendance 42.

Newark College of Engineering

Weston Heat Flow Meters and the Aviation Dynamo, by Francis Lamb, Weston Electrical Instrument Corp. Announcement made of the Student Convention to be held on April 25. March 10. Attendanec 34.

Resuscitation and Safety, by J. M. Orts, Public Service Co. of N. J., March 24. Attendance 30.

University of New Hampshire

Election of officers as follows: Arthur K. Whitcomb, Chairman; Carl B. Evans, Secretary. March 15. Attendance 44.

University of New Mexico

High-Frequency Currents, by Harold Deck, General Electric Co. March 4. Attendance 10.

College of the City of New York

Electrical Eyes in Communication, by Phillip C. Jones, Bell Telephone Labs., Inc. Illustrated. March 20. Attendance 35.

Combustion Practise and Fuel Burning, by A. E. Weichart, Combustion Engineering Corp. Joint meeting with the A. S. M. E., A. S. C. E., A. I. C. E. April 3. Attendance 82.

New York University

Automatic Train Control, by Leslie Weaver, Student;

Television, by D. Rotanelli, Student. G. Heller, Student, explained the use of the Polar Conversion Chart and illustrated its use by applying it to the solution of transmission problems. March 11. Attendance 16.

Railroad Conversion Equipment, by Ira Weston, Student;

Automatic Control, by Mr. Kunins, Student. March 25. Attendance 13.

North Carolina State College

Discussion of banquet plans. March 18. Attendance 30.

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Informal dinner preceded the meeting. March 26. Attendance 200.

Communications, by A. W. Hamrick, Student;

Insurance, by W. H. Harper, Student. April 1. Attendance 33.

University of North Carolina

Fifteen student members attended the meeting of the North Carolina Section held in Raleigh at which Professor Harold B. Smith, President, A. I. E. E., delivered his address, *The Quest of the Unknown*, March 26. Attendance 15.

The following day Professor Smith was guest of honor at a luncheon at the University. March 27.

Factory Tests on Large Turbo Alternators, by Professor E. W. Winkler. April 3. Attendance 18.

University of North Dakota

Ronald Olsen, Chairman, and Professor H. F. Rice, Counselor, gave reports of the Conference on Student Activities of District No. 6, held at the University of Wyoming. March 12. Attendance 18.

Atomic Hydrogen Welding Process, by John S. McKechnie, Student. Illustrated with slides. Charles Libby, Student, gave a talk on the power at Niagara Falls. March 26. Attendance 21.

Discussion of plans for annual Engineers Day. April 9. Attendance 21.

Notre Dame University

Mr. Duffy, Student, gave a talk on the comparison between steam- and hydro-power plants. Mr. Petrauskas, Student, discussed the subject of loud speakers. *Lubricating and Insulating Products*, by Mr. Hillman, Standard Oil Co. of Indiana. March 17. Attendance 60.

Ohio Northern University

The Electric Furnace, by Olin George, Student. March 20. Attendance 25.

Competition, by Professor F. L. Berger. April 3. Attendance 20.

Oklahoma A. & M. College

Oil Field Electrification, by Martin L. Hendrickson, Student;

Electric Arc Welding, by A. C. Nelson, Student. March 20. Attendance 15.

University of Oklahoma

Telephone Transmission Line Phenomena, by Earl Hassler, Student. Professor C. T. Almquist and Professor F. G. Tappan, Counselor, reported on the student meeting at the University of Missouri. March 26. Attendance 26.

University of Pittsburgh

The Early Oil Developments in Western Pennsylvania, by L. E. Smith, Student;

Wiring and Lightning, by K. A. Wing, Duquesne Light Co. February 27. Attendance 79.

Whaling, by B. A. Jones, Student;

Experiences After Graduation, by Mr. Patillo, Wagner Electric Co. March 5. Attendance 80.

W. C. Carl, Westinghouse Elec. & Mfg. Co., gave a talk on what to expect after graduation. *Determination of Cable Sizes*, by Mr. Reed, Bell Telephone Co. March 13. Attendance 84.

Cold Light, by J. K. Ely, Student;

Public Utilities as a Business Enterprise, by L. F. Blassingham, West Penn Power Co. March 20. Attendance 87.

Pratt Institute

Sound Picture Devices, by N. O. Rae, Student;

Elevator Control, H. A. Belanger, Student. April 8. Attendance 24.

Rensselaer Polytechnic Institute

A Review of Transmission Line Relaying, by L. F. Kennedy, General Electric Co. Nominating committee appointed to elect officers for next term. March 11. Attendance 80.

Transatlantic Telephony, by J. O. Perrine, American Tel. & Tel. Co. Election of officers as follows: C. E. Keeler, Chairman; F. S. Stidfole, Vice-Chairman; E. M. Lockie, Secretary. April 8. Attendance 305.

Rose Polytechnic Institute

N. A. Baptist, Student, gave a talk on fuses and their importance in the electrical industry. March 10. Attendance 22.

Rutgers University

Obtaining Records of Wave Forms with Curve Tracer, by G. E. Weglener, Branch Chairman;

Oscillographs, by E. R. Crawford, Branch Secretary. April 1. Attendance 11.

University of South Carolina

General discussion on: *Are the Chain Stores Beneficial to the Public?* March 21. Attendance 23.

South Dakota School of Mines

Report of the Conference on Student Activities of District No. 6 held at the University of Wyoming. Professor J. O. Kammerman, Counselor, also spoke on his trip to Laramie, and discussed some experiments carried on in research work. March 13. Attendance 16.

Some Engineering and Science Fakes, by Professor J. O. Kammerman, Counselor. Prof. E. E. Clark gave a talk on the inspection trip to the Homestake Mine at Lead, So. Dakota. April 10. Attendance 25.

University of Southern California

Clifford Westman told of the origin and development of the Big Creek Power Project now controlled by the Southern California Edison Co. and of some of his experiences while employed with that company. Arthur Cutts told of his experiences in the Test Department of the Bureau of Power & Light of the City of Los Angeles. March 12. Attendance 35.

General discussion and announcements. March 19. Attendance 36.

Film—"Single Ridge." March 26. Attendance 35.

Southern Methodist University

Ben. Beaird, Chairman gave an account of the student meeting of the 7th District held at Columbia, Mo. March 28. Attendance 12.

Syracuse University

Parallel Operation of Transformers, by M. J. Wright, Student. January 13. Attendance 10.

The Deion Circuit Breaker, by Clinton Hurlbut, Student. February 10. Attendance 10.

Automatic Train Control, by Charles Pierce, Student. February 17. Attendance 10.

The Evolution of the Lightning Arrester, by George Haaf, Student. February 24. Attendance 10.

The Mercury Arc Rectifier, by Clifford Tallcott, Student. March 3. Attendance 10.

Film—"On the Firing Line." March 10. Attendance 10.

The Cathode Ray Oscillograph, by George Haaf, Student. March 17. Attendance 10.

University of Tennessee

Address by Professor W. S. Rodman, Vice-President, District No. 4, A. I. E. E., on the aims and activities of the Institute, March 17. Attendance 18.

Address by E. J. Walsh, Chattanooga Boiler Works. Banquet meeting. March 1. Attendance 250.

Texas A. & M. College

Railroad Signals, by J. M. Tomme, Student. March 14. Attendance 32.

Dance. March 28.

Talk on the R. C. A. Photophone. The following films presented: "The Electric Ship," "The Conquest of the Cascades," 'The Romance of Power," "The Hottest Flame Known." April 7. Attendance 225.

Texas Technological College

Recent Developments in the Electrical Industry, by Walter N. Burns, Student. Report of the meeting at the University of Missouri by W. E. Street, Chairman, and Dean Wm. J. Miller, Counselor. March 26. Attendance 14.

University of Texas

Annual Banquet. *The Purpose of the Student Branch*, by Professor J. A. Correll, Counselor. B. D. Hull, Vice-President, District No. 7, A. I. E. E., gave a talk on some of the recent accomplishments of the Institute. March 11. Attendance 55.

University of Utah

The History of the Electric Motor, by I. R. Walton, Wagner Electric Corp. Slides. March 14. Attendance 19.

The Electric Eye, by H. T. Plumb, General Electric Co. Joint meeting with the Utah Section. March 20. Attendance 290.

Lecture describing some of the problems arising in the installation of natural gas, by C. M. Ware, Utah Gas & Coke Co. April 1. Attendance 36.

Virginia Military Institute

Film—"The Continuous Process for Making Sheets." March 10. Attendance 83.

Film—"From Pigs to Pigment." March 12. Attendance 81.

The following talks presented by Students:

The Deion Grid, by Mr. Romm;

The Lavino Furnace, by Mr. Mills;

Steinmetz The Man and The Genius, by Mr. King;

Magnetic Clutches, by Mr. Richards. April 11. Attendance 54.

University of Wisconsin

Mr. Woodford, Student, gave a report of the District meeting held in Chicago. *System Interconnection*, by Mr. Weber, Student;

The Analytical Criticism of the Electrical Engineering Course, by E. A. Johnson, Student. February 19. Attendance 26.

Film—"The Single Ridge." March 19. Attendance 21.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these founder societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August, when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, MARCH 1-31, 1930

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

AIRCRAFT YEAR BOOK, 1930.

By Aeronautical Chamber of Commerce of America. N. Y., D. Van Nostrand Co., 1930. 647 pp., illus., diagrs., maps, 9 x 6 in., cloth. $6.00.

A valuable reference book for every one interested in aeronautics. Contains an account of developments during 1929 in all branches of aviation. Progress in manufacturing, in military and civil aviation, aeronautical legislation, etc., are reviewed fully. Sketches of a large number of aircraft and engines are included.

ATOMS, MOLECULES AND QUANTA.

By Arthur Edward Ruard and Harold Clayton Urey. N. Y., McGraw-Hill Book Co., 1930. (International series in physics). 790 pp., illus., diagrs., tables, 9 x 6 in., cloth. $7.00.

This book aims to meet the needs of students beginning the study of atomic and molecular structure, and also to furnish workers in this field with an up-to-date account of the laws of quantum theory and a general account of the important experimental researches. The history and chief experimental facts of the quantum theory and the progress of knowledge of atomic and molecular structure prior to the introduction of the new mechanics occupy the first fourteen chapters. The fundamental ideas of quantum mechanics are then developed. The last chapter discusses the wave properties of material bodies.

DIE BERECHNUNG DER ANHEIZUNG UND AUSKÜHLUNG EBENER UND ZYLINDRISCHER WÄNDE.

By W. Esser and O. Krischer. Berlin, Julius Springer, 1930. 88 pp., diagrs., plates, tables, 11 x 8 in., paper. 15.-r. m.

Two essays on the heating and cooling of buildings and pipe systems. The first by Dr. Krischer, deals with the cooling of plane and cylindrical walls from the stationary condition, and with their heating by an uninterrupted flow of heat. A simple method of calculating the changes is developed, which approximates closely the results of exact analytic calculations.

The second essay, by Dr. Esser, describes an experimental investigation of the cooling of insulated pipe and gives a simplified method of calculating heat losses. Numerical tables are provided which make it easy to apply the method to practical problems of heat insulation.

BONBRIGHT SURVEY OF ELECTRIC POWER AND LIGHT COMPANIES OF THE UNITED STATES. 6th edition, revised to December 1929. Edited by G. F. Wittig. N. Y., McGraw-Hill Publ. Co., 1930. 194 pp., maps, 11 x 9 in., paper. $10.00.

A series of maps and tables by means of which an electric company is identified with every town and city of at least 2500 inhabitants. The salient facts concerning each company are given: capital, indebtedness, earnings, and interest. A few characteristic facts about each state are included. The book gives a very definite picture of the electric light and power industry.

ELECTROPLATING WITH CHROMIUM, COPPER AND NICKEL.

By Benjamin Freeman and Frederick G. Hoppe. N. Y., Prentice-Hall, 1930. 212 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

A practical guide for the electroplater, covering the electrochemical principles involved, the preparation of the work, the preparation of baths, the equipment, and the methods of plating. Special attention is given to chromium plating. The authors are connected with the National Chromium Corporation.

DIE ELEKTRISCHEN KABEL.

By H. Heinzelmann. Ber. u. Lpz., Walter de Gruyter & Co., 1930. 133 pp., illus., diagrs., tables, 6 x 4 in., cloth. 1,80 r. m.

Materials and methods of manufacturing electric cables for power and for communication are described briefly in this little manual, which is intended especially for engineers who are not specialists in this field, but who desire a general knowledge of the subject.

DIE ELEKTRISCHEN SCHWEISSVERFAHREN.

By Hch. Krökel & Hans Niese. Ber. u. Lpz., Walter de Gruyter & Co., 1930. 136 pp., illus., 6 x 4 in., paper. 1,80 r. m.

A concise practical manual on welding, describing apparatus and methods, advantages of electric welding, tests, etc.

DAS FERNSPRECHWESEN, pt. 2; Fernsprechanlagen für Handbetrieb.

By H. Schmidt. Ber. u. Lpz., Walter de Gruyter & Co., 1930. 123 pp., illus., diagrs., 6 x 4 in., cloth. 1,80 r. m.

Manually-operated telephone systems are outlined in this work. Beginning with the simplest telephones, the author describes house telephone systems of various kinds, and leads to large manual switchboard systems.

GMELINS HANDBUCH DER ANORGANISCHEN CHEMIE, Bd. 59; Eisen, Teil B, Lief. 2. 8th edition. Edited by Deutsche Chemische Gesellschaft. Ber., Verlag Chemie, 1930. p. 313-512, 10 x 7 in., paper. 32.-r. m., or 25.-r. m. by subscription to entire work.

This section of the great encyclopedia of inorganic chemistry treats the compounds of iron with bromine, iodine, sulfur, selenium, tellurium, boron, and carbon. It summarizes all the available data on the physical and chemical properties of these compounds and on their chemical behavior. The book is indispensable in any chemical library.

HILFSBUCH FÜR BETRIEBSBERECHNUNGEN.

By B. M. Konorski. Berlin, Julius Springer, 1930. 137 pp., tables & 46 plates. 12 x 9 in., cloth portfolio. 28,50 r. m.

A collection of formulas, tables and nomographic and linear charts intended to facilitate practical engineering computation.

Covers mechanics, heat, the strength of materials, machine elements, boilers, illuminating engineering, electrical engineering, the steam consumption and efficiency of boilers and turbines, pumps, and fans. The aim has been to include methods giving the necessary accuracy with the least amount of work. Forty-six monograms are included.

HOCHSPANNUNGS-FREILEITUNGEN.

By Kurt Draeger. Ber. & Lpz., Walter de Gruyter & Co., 1930. 173 pp., illus., diagrs., tables, 6 x 4 in., cloth. 1,80 r. m.

A good brief introduction to overhead high-voltage lines. The data required for their calculation and construction are provided, together with practical examples. Both mechanical and electrical considerations are discussed.

INDUSTRIAL ELECTRICITY AND WIRING.

By James A. Moyer and John F. Wostrel. N. Y., McGraw-Hill Book Co., 1930. 469 pp., illus., 8 x 6 in., cloth. $2.75.

A text-book for students of wiring practise which presents the underlying principles of electrical theory and also the details of standard wiring practise for various purposes, as given in the National Electric Code. Wiring methods are also explained.

JOURNAL, v. 2, pt. 2, Jan. 1930, Royal Technical College (Glasgow). Glasgow, The College, 1930. p. 161-366, illus., diagrs., tables, 10 x 7 in., paper. 10s 6 d.

Contains reports on various researches carried out at the College. Among those of interest to engineers are investigations of mica insulation, of the effect of tensile strain on the magnetostriction of steel, on friction coefficients for fabric brake linings, on heat transmission in surface feed-heaters, and on direct and bending stresses in circular flat plates.

LATEX, its Occurrence, Collection, Properties and Technical Applications.

By Ernst A. Hauser. Translated by W. J. Kelly. N. Y., Chemical Catalog Company, 1930. 201 pp., illus., 9 x 6 in., cloth. $4.00.

An exhaustive survey of the literature on latex, up to April, 1927. Sources, collection, physical and chemical properties, etc. are discussed with full references to original publications. An appendix contains an annotated list of the English and German patents on the working of latex. The monograph will be very useful to all investigators of rubber.

MEHRFACHFUNKENAUFNAHMEN VON EXPLOSIONSVORGÄNGEN NACH DER TOEPLERSCHEN SCHLIERENMETHODE.

By Werner Lindner. (Forschungsarbeiten. Heft 326). Berlin, V. D. I. Verlag, 1930. 18 pp., illus., 11 x 9 in., paper. 4.-r. m.

Describes an optical process for investigating the phenomena of combustion in gas-engine cylinders. A series of photographs, taken at extremely small intervals, shows the propagation of the flame front from the point of ignition to the walls. Results of tests are included.

METALLOGRAPHIE DER TECHNISCHEN KUPFERLEGIERUNGEN.

By A. Schimmel. Berlin, Julius Springer, 1930. 128 pp., illus., diagrs., 10 x 7 in., paper. 19.-r. m.

A handbook on the metallography of commercial alloys of copper, which aims to provide a book for the testing laboratory similar to those available on iron and steel. Micrographic and monographic methods of examining these alloys are given and the interpretation of the results explained. Theoretical considerations are subordinated to practical use.

PHOTOELECTRIC CELLS, THEIR PROPERTIES, USE AND APPLICATIONS.

By Norman Robert Campbell and Dorothy Ritchie. Lond. & N. Y., Isaac Pitman & Sons, 1929. 209 pp., diagrs., tables, 9 x 6 in., cloth. $4.50.

Considers this cell as a practical tool for the laboratory and shop, rather than as an illustration of physical laws. The book is based on the investigations of the authors, who are members of the research staff of the British General Electric Company.

PIONEERS OF ELECTRICAL COMMUNICATION.

By Rollo Appleyard. N. Y. & Lond., Macmillan Co., 1930. 347 pp., illus., ports., 9 x 6 in., cloth. $6.50.

Maxwell, Ampère, Volta, Wheatstone, Hertz, Cersted, Ohm, Heaviside, Chappe and Ronalds are the subjects of ten memoirs here presented. Mr. Appleyard discusses their lives in an interesting way and illustrates his accounts with portraits and illustrations of the original apparatus used by these pioneers. The personal side is given attention, as well as the scientific. A welcome contribution to electrical history.

PRINCIPLES OF ELECTROPLATING AND ELECTROFORMING.

By William Blum and George G. Hogaboom. 2d edition. N. Y., McGraw-Hill Book Co., 1930. 424 pp., illus., diagrs., tables, 9 x 6 in., cloth. $4.50.

This comprehensive review of the subject has as its chief purpose the more effective correlation of principles and practise. The chemical and electrochemical principles involved, the factors governing the quality of deposited metal are discussed clearly. Advice is given on equipment, on the preparation of work for plating, etc., and separate chapters are devoted to copper, nickel, chromium, zinc, silver, gold, and the other commercial metals. The new edition has been revised, and enlarged where important progress has occurred.

PRIOFORM-HANDBUCH.

By Deutsche Prioform Werke Bohlander & Co., Köln. Ed. 2. Berlin, Julius Springer, 1930. 283 pp., tables, 7 x 5 in., cloth. 15.-r. m.

A handbook for engineers interested in heat insulation, containing a concise presentation of the principles of the subject and of the application of theory to practical problems. About one-half of the book is devoted to physical and chemical tables of use in the design and use of insulating materials. The book is a useful reference work.

QUESTIONS AND ANSWERS ON . . . DIESEL, SEMI-DIESEL AND OTHER INTERNAL COMBUSTION ENGINES, AIR COMPRESSORS, ETC.

By John Lamb. 3rd edition. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1929. 340 pp., 7 x 4 in., cloth. $6.00.

A catechism of Diesel engine operation, designed for marine operating engineers, and as a preparation for Board of Trade examinations for licenses.

REGELN FÜR DIE PRÜFUNG VON WÄRME-UND KÄLTESCHUTZANLAGEN.

Berlin, V. D. I. Verlag, 1930. 16 pp., tables, 11 x 8 in., paper. 4.-r. m.

A standard code for delivery tests of heat insulation materials, sponsored by the Verein Deutscher Ingenieure. Methods of calculating heat losses, guaranties, and methods for testing insulating materials are described. A bibliography is included.

THEORETISCHE PHYSIK. By Gustav Jäger.

v. 1. Mechanik.—v. 2. Schall u. Wärme.—v. 3. Elektrizität und Magnetismus.—v. 4. Optik.—v. 5. Wärmestrahlung, Elektronik und Atomphysik. Ber. u. Lpz., Walter de Gruyter & Co., 1930. 5v. 6 x 4 in., cloth. 1,80 r. m. each.

These five small volumes, by the professor of physics at Vienna University, are a concise, but comprehensive, survey of modern theoretical physics. This new edition has been rewritten and rearranged, as well as enlarged, and space has been found for the latest developments.

DIE WÄRMEAUFNAHME DER BESTRAHLTEN KESSELHEIZFLÄCHE.

By Otto Siebert. (Forschungsarbeiten, heft 324). Berlin, V. D. I. Verlag, 1930. 17 pp., illus., tables, 11 x 8 in., paper. 4.-r. m.

The high temperatures under which boilers are operated today have not only increased their efficiency, but have also increased the danger of injuries to the tubes. As these frequently occur at points subjected to direct radiation, the author has been led to investigate mathematically the absorption of radiant heat.

This paper presents a method for determining the amount of heat radiated to a surface, which agrees closely with actual measurements.

X-RAY TECHNOLOGY.

By H. M. Terrill and C. T. Ulrey. N. Y., D. Van Nostrand Co., 1930. 256 pp., illus., diagrs., 9 x 6 in., cloth. $4.50.

A manual for the X-ray laboratory by two experienced physicists. Attention is concentrated upon the practical aspects of X-ray measurements, especially as applied in therapy and industry. Much space is given to describing instruments and apparatus, and methods of using them.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contribution from the societies and their individual members who are directly benefited.

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MEN AVAILABLE—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

EXPERIENCED TRANSFORMER DESIGN ENGINEERS, men with experience in the design of large power transformers preferred. Only high grade men need apply. W-600.

SALES ENGINEER, thoroughly familiar with sound equipment in all branches. Technical training required. Must have following with manufacturing trade. Drawing against commission. Apply by letter. Location, New Jersey. W-833.

MANUFACTURERS' REPRESENTATIVES. covering jobbers and manufacturers of electrical and radio apparatus in New England, Atlantic seaboard, eastern, middle west, northwest and southwest districts. Apply by letter. Headquarters, New Jersey. W-834.

INSTRUCTOR, to conduct recitation and laboratory classes in electrical measurements, and assist in senior a-c. laboratory, with the possibility of advanced problem work. Should be a graduate in electrical engineering and must be well grounded in electrical theory with preferably some advanced courses though not necessarily an advanced degree. Apply by letter. Location, Middle west. W-874-C.

INSTRUCTOR, for elementary work in recitation and laboratory courses for non-electrical students of junior grade. Should be a graduate in electrical engineering with practical experience and some familiarity with industrial problems. Apply by letter. Location, Middle west. W-875-C.

ASSISTANT PROFESSOR, electrical engineer, with teaching experience and preferably some practical engineering achievements. Will be in charge of the electrical laboratory and will have some lecture work. Salary $3000 a year. Apply by letter. Location, South. W-858.

INSTRUCTOR for electrical engineering laboratory. Recent graduate from an engineering school of good standing, who is interested in teaching and experimental work should qualify. Salary $1800 a year. Location, South. Apply by letter. W-859.

SALES ENGINEER, with structural experience, especially in field of electrical public utilities. Apply by letter. Location, New York State, but some traveling will be required. W-963.

MEN AVAILABLE

ELECTRICAL ENGINEER, M. I. T. Graduate, single, age 24. One year with midwestern utility; one year research laboratory. Experienced oscillograph operator. Desires connection with utility or engineering office-laboratory. Will go anywhere. Available on two weeks notice. C-7199.

ELECTRICAL AND MECHANICAL ENGINEER, 29, married; five years' experience in test, application, maintenance and design. Post two years' in charge of electrical department for mining company. Desires connection as assistant plant engineer or assistant electrical engineer with industrial. Good personality; can handle men; willing to assume responsibility. Now employed. B-9001.

GRADUATE ELECTRICAL ENGINEER, single 24, three years' experience with public utility company including year of mechanical and electrical testing in large power plants and in smaller industrial plants. Also office and field work in connection with relay maintenance. Desires position in operating department of public utility. C-7138.

1928 GRADUATE ELECTRICAL ENGINEER, 27, desires position with good chances for advancement in either research or design work on electrical apparatus. Has had two years' experience as a Service Engineer in the installation and repair of x-ray and electrotherapeutic apparatus; also some experience in motor control work. Good recommendations. C-4220.

ELECTRICAL ENGINEER, Swiss university graduate, 36, American, 15 years' test and designing experience with known European and American manufacturing and public utility companies. Desires position with public utility or traction company in engineering-operating or sales department, where conscientiousness and dependability of character is of value. Available at once. C-7183.

ELECTRICAL ENGINEER, 9 years' engineering experience. Experience covers design and construction of overhead distribution and transmission systems; underground a-c. networks and distribution systems; switchboard and substation design and operation. Executive ability. At present assistant distribution engineer. Location, Southwest or South. C-4734.

M. I. T. GRADUATE, ELECTRICAL ENGINEER, 34, married, desires teaching position in College E. E. course beginning next fall. Six years' research and industrial experience including G. E. Co. and Bureau of Standards. Two years' experience. Best of references. Middle west or South preferred. C-2826.

ELECTRICAL ENGINEER, 34, married, degree E. E. Dordrecht, Holland. Languages; English, Dutch, French, German. Desires position as construction engineer with prospects of foreign service now or later. Available for any location. Seven years' experience, installation, testing, automatic telephone inspector central office, emergency repairing, draughting, supervisory control. Now employed. C-5733.

INSTRUCTOR, with 11 years' teaching experience in southern university of recognized standing. Electrical machinery design, advanced laboratory, telephone and radio courses. Thoroughly in touch with modern practises through consulting work with industrial concerns. B. S. 1917, advanced course since graduation, 36, married. Available in September. B-3378.

FACTORY MANAGER, 45, 26 years' experience in manufacturing of all kinds of copper wire; has also had the planning and installation of large amounts of new equipment. C-7195.

ENGINEER, ELECTRICAL AND CIVIL, partner in firm engaged design, development, manufacture, promotion and sale of processes, machines-automatic, or meritorious inventions for quantity production. Desires additional projects; will work as individual for or with firms or individuals. If mutually agreeable, work can be done by his firm. Excellent manufacturing and sales connections. B-9945.

ELECTRICAL ENGINEER, American, 39, married. Experienced in power generation, transmission, distribution and application to industrial uses. Work covers layout, construction, operation, maintenance and repairs. Desires position as electrical engineer with manufacturing company. Speaks Spanish. Available on reasonable notice. C-502.

TEACHER OF ELECTRICAL ENGINEERING, age 34, hold degrees of B. S., B. S. in E. E. and E. E. (by resident graduate work) obtaining M. S. this year. Good scholastic and personal records. Twelve years' experience. Desires permanent position in southern or western engineering school or college grade. C-1599.

GRADUATE ELECTRICAL ENGINEER, now completing the design of an important power station, is available for a new position. Experience includes testing, drafting, construction and supervision of design. Will take responsible charge of electrical plans for steam or hydroelectric project, including estimates, specifications and reports. B-4022.

ELECTRICAL ENGINEER, ten years' experience design, erection, operation, central stations, overhead, underground, transmission, distribution, industrial plants, radio communication; specifications, estimates, reports, sales. Recently arrived from Orient; assistant electrical engineer, designing, erecting and operating light and power equipment very large sugar mill, distillery

Fluent knowledge, Spanish, German. Executive ability. Best of references. C-7205.

ELECTRICAL ENGINEERING TEACHER, two degrees, 31, married, two and one-half years G. E. Test and Engineering Department, five years' public utility work, two and one-half years teaching E. E., one year as head of department. Desires change. Excellent references. Location, immaterial. C-7152.

ELECTRICAL ENGINEER, 32, married, 12 years' experience, design, layout, construction, maintenance, repair large industrials, three years' modern custom repair shop practise. Thoroughly familiar modern power equipment, repair shop practise, mass production requirements. Desires responsible connection large utility, industrial plany, large repair shop. Can effect appreciable economies in repair shop practise. Middle western location preferred. C-5916.

ELECTRICAL ENGINEER, over 20 years' experience, including two years' as associate physicist at Bureau of Standards. Last five years full professor of Electrical Engineering in leading technical school. Specialist in theoretical and mathematical analysis of engineering problems; research, design, and invention. Broad knowledge of radio. Location, preferred, South or East. C-6141.

ELECTRICAL-MECHANICAL ENGINEER, 10 years' experience, design, development, manufacture, a-c., d-c. motors, generators, converters, electroplaters, elevator motors, special machines. Broad experience application engineering. Good knowledge modern shop practise, ability to coordinate designing, manufacturing. Well versed in German. Now employed in executive capacity. Desires position of responsibility. College graduate, 32, married. C-1801.

TRANSMISSION ENGINEER, 36, University graduate, 13 years' experience in transmission line field. Able to take complete charge of work. Available on limited notice. C-2014.

GRADUATE ELECTRICAL ENGINEER, age 28, single, five years' experience in overhead transmission and distribution system design, operation, and maintenance. Desires position with public utility requiring services of man with above qualifications. Now employed. C-7190.

ELECTRICAL ENGINEER, with one and one-half years' General Electric Test experience, nine years' railroad lighting and power work and four years' college E. E. teaching experience desires college E. E. course teaching. C-6490.

MINING ELECTRICAL ENGINEER, technical graduate, estimating, planning and supervision of electrical erection in mines, power plants, substations and etc. Experienced in handling different kinds of labor and assume responsibilities. Wide experience in foreign fields. Speaks Spanish fluently but native born American. Desire position with mining company. Available short notice. C-5457.

ELECTRICAL ENGINEER, technical graduate, American, 23 years' experience designing, estimating, construction, operation of power, substations, lighting, distribution. Conversant with reports, valuation, appraisals. Thoroughly acquainted, street railway, subway, elevated work. Has handled 400 men successfully, not afraid to assume executive responsibility. Desires position, large utility, consulting engineers, with industry as plant engineer. C-7202.

GRADUATE ELECTRICAL ENGINEER, with 12 years' of experience in research, development and design of small apparatus. Thoroughly familiar with low-tension (up to 220-volt) signaling and control apparatus and equipment. Had charge of research and development work in two large organizations. Qualified for a position calling for creative work on small apparatus. Available on short notice. C-3820.

MEASUREMENT AND CONTROL SPECIALIST, seeks connection with commercial laboratory, public utility or manufacturer, in capacity of developing engineer or consultant. Wide and extensive experience with all types of electrical instruments, precision measurement, standardization and automatic control. Also experienced in pyrometry and automatic control. Correspondence invited. B-7245.

TECHNICAL GRADUATE, 30, married, ten years' experience on steam and hydroelectric systems as operator and system operator. Desires position as load dispatcher or system operator. Now employed. Location, New England or West Coast preferred. C-7267.

ELECTRICAL GRADUATE, 36, just returned from South America. Long experience construction of central stations, substations, allied lines, maintenance, tests, inspections, distributions, pole lines, one year operating. Desires position foreign, home, or representative to manufacturers in Brazil, elsewhere. Languages, English, French, Portuguese, working knowledge Spanish, Italian, German. Best references, available immediately. C-2021.

ELECTRICAL ENGINEER, 28, B. S. degree, several years' experience in design and construction of distribution and transmission systems, substations, plant and railroad installations, also operating experience. Desires new connection with greater opportunities. Now located in New England. B-998.

INSTRUCTOR, Electrical Engineering. Position desired by Columbia University graduate, holding B. S., E. E. degrees (6-year course). At present engaged, high-voltage research work. Has two years' European manufacturing, three years' American public utility experience. Linguistic qualifications; German, French. To teach either d-c. or preferably a-c. classes and laboratory work. C-930.

EXECUTIVE ELECTRICAL ENGINEER, 39, married; with extensive Latin-American experience; capable of taking complete field managerial charge operating, construction, public relations, new business, development work along acquisition lines. Desires connection public utility, engineering company, with either domestic or foreign properties. Well acquainted Latin-American requirements for obtaining concessions, contracts, etc. Available. C-761.

TECHNICAL GRADUATE, 36, married. G. E. Test—15 months. Varied experience including operating and construction, four years. Lineman one year. Transformer designer, five years. Motor sales one and one-half years. Industrial power one year. Public utility salesman three years. Wants connection with future. C-7228.

ELECTRICAL ENGINEER, university graduate, age 31, with eight years' of transmission, distribution, substation design and planning, construction, reports, operating, calculations, drafting. Utility cadet course. Speaks German, French, Russian. Desires connection with consulting engineer or utility. Russia or South America considered. B-8043.

RECENT GRADUATE, E. E., 37, single, practical experience in motor repair and wiring, speaks German and Spanish. Desires position, East or Middle west. C-7246.

ASSISTANT PROFESSOR OF E. E., B. S. in E. E., M. S. in Eng., 31, married. Five years' of teaching and practical experience, now employed by a prominent southern university as assistant professor in E. E. Desires permanent teaching position in Eastern institution. C-4368.

ELECTRICAL ENGINEER, 15 years' teaching, consulting experience. At present head, Dept. of Electrical Engineering in one of the large southern universities. Have been employed in consulting capacity on transmission work, explosions, railroad accidents, etc. Best of references. Has been engaged to write on public utilities for newspapers. Age 36; family. C-6288.

GRADUATE ELECTRICAL ENGINEER, 28, married, nine years' experience in engineering, construction and operation of overhead and underground distribution and transmission. Particularly fitted for economic studies, system design, phase changeovers and overhead construction. Last five years in supervisory capacities. Location, immaterial. B-9408.

EXPERIENCED METER ENGINEER, 36, technical graduate. Familiar with all types of metering, also power-plant equipment, distribution systems and public utilities operations. Executive ability. Desires change to growing property. Location preferred, eastern states. C-7295.

ELECTRICAL ENGINEER, technical graduate, 1924, age 29, married. General Electric Test, Industrial Control Engineering Department, two years' university instructor in electrical engineering. Desires permanent connection with consulting engineering firm, public utility, or industrial concern. Pacific Coast location preferred. Now employed. C-7296.

PUBLIC UTILITY ENGINEER, age 33, electrical engineering graduate with knowledge of corporation finance and 10 years' experience in consulting service on railway, bus, and electric light operation, appraisals and public utility regulation problems in major cities throughout the country, would like connection with large operator or holding company. B-446.

ASSISTANT PROFESSOR, or instructor in electrical engineering. Two years' development engineer on communication apparatus. Five years' head of Electrical Department in large industrial school. At present on E. E. staff of recognized university, teaching electrical design and other electrical engineering subjects. Available in September. C-2893.

GRADUATE ENGINEER, 36, married, with 10 years' experience, manufacturing, production, standardization and general industrial engineering, in diversified industries, principally electrical. Also two years' sales in eastern states. Available now. Location, preferably in eastern states. C-7303.

ELECTRICAL ENGINEER, technical graduate, four years' experience as a cable research engineer with a prominent testing company. Desires position with a utility or a cable manufacturer. Location, immaterial. C-7308.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held April 23, 1930, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed with the National Secretary at once.

To Grade of Fellow

BARKER, JOSEPH W., Prof. and Head of Dept. of E. E., Lehigh University, Bethlehem, Pa.

COOK, JAMES A., Supt. Elec. Dept., Lynn Gas & Elec. Co., Lynn, Mass.

DEANS, WILLIAM, Chief Engineer, Sundh Electric Co. Inc., Newark, N. J.

JACKSON, Jr., DUGALD C., Prof. and Head of Department of Mechanical and Electrical Engineering, Speed Scientific School, Louisville, Ky.

SEARING, HUDSON R., Assistant Electrical Engineer, United Electric Light and Power Co., New York, N. Y.

VINCENT, HAROLD B., Manager Field Engg. Service, The R. Thomas & Sons Co., Lisbon, Ohio.

To Grade of Member

ANSON, EDWARD H., Asst. Catenary Engr., Jackson & Moreland, Hoboken, N. J.
CURRIN, H. P., Chief Elec. Engr., City of Eugene Electricity Utility, Eugene Water Board, Eugene, Oregon.
EVELEV, YALE, Electrical Engineer, Keystone Engg. Co., Reading, Pa.
GAARDEN, OSCAR, Valuation Engineer, Northern States Power Co., Minneapolis, Minn.
GAINES, EARL L., Traffic Supt., The Home Telephone & Telegraph Co., Fort Wayne, Indiana.
GOODLET, BRIAN L., Section Engineer, Metropolitan Vickers Elec. Co. Ltd., Trafford Park, Manchester, England
JUMP, GEORGE H., Engineer, General Elec. Co., Buffalo, N. Y.
KELLY, JOSEPH B., Member of Technical Staff, Bell Telephone Labs., Inc., New York, N. Y.
KIRK, RALPH L., Asst. to System Development Manager, Duquesne Light Co., Pittsburgh, Pa.
KISTLER, ROY E., Protection Engr., Pacific Tel. & Tel. Co., Seattle, Wash.
LECONTE, ROBERT A., Member of Technical Staff, Bell Telephone Labs., Inc., New York, N. Y.
MARBURY, RALPH E., Electrical Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
McCULLOUGH, LEE WILLIAM, Asst. to Elec. Engr., United Electric Light and Power Co., New York, N. Y.
MEKELBURG, EARL F., Chief Engineer, Union Electric Mfg. Co., Milwaukee, Wis.
MEURER, SYLVAIN T., Division Engineer, N. Y. & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
MILNE, GORDON R., Engineer, Inside and Outside Plant Engr., United Electric Light & Power Co., New York, N. Y.
MORGAN, JOSEPH M., Electrical Engineer, General Water Works and Elec. Corp., Kingstree, S. C.
O'NEAL, LLOYD E., Sales Engineer, Delta-Star Elec. Co., Chicago, Ill.
THOMAS, EARL R., General Engineer, United Electric Light and Power Co., New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1930.

Abbott, R. W., Commonwealth Edison Co., Chicago, Ill.
Adams, L. O., (Member), General Electric Co., Louisville, Ky.
Allen, W., E. I. du Pont de Nemours Co., Wilmington, Del.
Alter, J. M., Pennsylvania Railroad, West Philadelphia, Pa.
Ansteth, M. C., Niagara, Lockport & Ontario Power Co., Lockport, N. Y.
Armstrong, G. R., Louisville Gas & Elec. Co., Louisville, Ky.
Ayers, S. L., Niagara Hudson Power Corp., Utica, N. Y.
Baldwin, I. W., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Bassett, L. G., English Electric Co. of Canada, Ltd., Toronto, Ont., Can.
Bayard, R. A., Roessler & Hasslacher Chemical Co., Niagara Falls, N. Y.
Bergey, D. O., Westinghouse Electric International Co., New York, N. Y.
Bigelow, G. H., United Elec. Lt. & Pr. Co., New York, N. Y.
Bixler, J. E., Jr., Duncan Electric Mfg. Co., Lafayette, Ind.
Blau, E. W., Pacific Tel. & Tel. Co., San Francisco, Calif.
Bliss, F. W., General Electric Co., Boston, Mass.
Boe, H. F., (Member), Westinghouse Elec. & Mfg. Co., Buffalo, N. Y.
Booker, J. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Brake, D. K., Mountain States Tel. & Tel. Co., Helena, Mont.
Brown, P. A., City of Tacoma, Tacoma, Wash.
Bryan, W. S., Puget Sound Pr. & Lt. Co., Seattle, Wash.
Caffee, H. G., Western Electric Co., Chicago, Ill.
Cannon, C. E., Washington Water Power Co., Spokane, Wash.
Carter, C. W., Virginia Public Service Co., Charlottesville, Va.
Coggeshall, I. S., Western Union Tel. Co., New York, N. Y.
Cole, B. T., Westinghouse Elec. & Mfg. Co., Buffalo, N. Y.
Cookson, G. B., Chicago Central Station Institute, Chicago, Ill.
Copans, W. J., United Electric Lt. & Pr. Co., New York, N. Y.
Cost, J. N., Western Electric Co., Chicago, Ill.
Crawford, F. D., Brooklyn Edison Co., Brooklyn, N. Y.
Crossley, W. R., Underwriters Association, Wilmington, Del.
Cutting, C. A., Drawer 188, Humboldt, Sask., Can.
Daniels, T. E., Commonwealth Edison Co., Chicago, Ill.
Davis, H. V., City of Revelstoke, Revelstoke, B. C., Can.
Davis, M. M., United Engineers & Constructors, Philadelphia, Pa.
Davis, S. W., Cosden Oil Co., Big Spring, Tex.
Deyoe, H. L., New York Edison Co., New York, N. Y.
Drack, P., Commonwealth Edison Co., Chicago, Ill.
Evans, K., Commonwealth Edison Co., Chicago, Ill.
Eyres, S. A., Westinghouse Elec. & Mfg. Co., Buffalo, N. Y.
Farmer, F., Detroit Edison Co., Detroit, Mich.
Francis, A. D., City of Tacoma, Tacoma, Wash.
Freeman, R. B., Commonwealth Edison Co., Chicago, Ill.
Freidenmann, J. W., (Member), General Electric Co., Pittsburgh, Pa.
Fritschel, E. P., Public Service Co. of No. Illinois, Waukegan, Ill.
Fults, H. S., Los Angeles Bureau of Pr. & Lt., Los Angeles, Calif.
Galassin, J. P., Commonwealth Edison Co., Chicago, Ill.
Garvey, F. A., (Member), Stevens & Woods, Inc., Saginaw, Mich.
Gerhardt, R. C., Niagara, Lockport & Ontario Power Co., Lockport, N. Y.
Goetcheus, M. L., New York Edison Co., New York, N. Y.
Goss, L. F., Kuhlman Electric Co., Bay City, Mich.
Gothberg, A. W., Public Service Electric & Gas Co., Newark, N. J.
Griffith, A. W., National Aniline & Chemical Co., Buffalo, N. Y.
Hardie, C. G., (Member), Oldbury Electro-Chemical Co., Niagara Falls, N. Y.
Hart, F. G., Ohio Brass Co., Mansfield, Ohio
Hill, F. M., 29 Whitney Ave., New Havem, Conn.
Hortberg, R. O., Commonwealth Edison Co., Chicago, Ill.
Hudson, R. A., Goodyear Zeppelin Co., Akron, Ohio
Jain, E. W., Commonwealth Edison Co., Chicago, Ill.
Jehlicka, L. J., Commonwealth Edison Co., Chicago, Ill.
Johns, H. H., Southwest Cotton Co., Goodyear, Ariz.
Johnson, E. T., (Member), Westinghouse Elec. & Mfg. Co., New York, N. Y.
Kegg, K. L., Weyerhaeuser Timber Co., Klamath Falls, Ore.
King, A. P., Carnegie Institute of Washington, Pasadena, Calif.
Koontz, L. L., Shenandoah River Power Co., Harrisonburg, Va.
La Grange, A. M., Public Service Co. of No. Illinois, Chicago, Ill.
Lane, G. L., Washington Water Power Co., Spokane, Wash.
Lawall, R. M., American Tel. & Tel. Co., Cleveland, Ohio
Lewis, D., Aluminum Co. of America, Detroit, Mich.
Lewis, W. E., Pennsylvania Power & Light Co., Bethlehem, Pa.
Lidsky, L. L. & P. Electric Co., Brooklyn, N. Y.
Lieberkind, H. E., West Penn Power Co., Pittsburgh, Pa.
Litz, S. J., Elmira Water Light & Railroad, Elmira, N. Y.
Lundstrom, A. A., Oregon State College, Portland, Ore.
Lyon, G. W., (Member), Westinghouse Elec. & Mfg. Co., New York, N. Y.
Mack, H. M., Mountain States Inspection Bureau, Denver, Colo.
Mackay, W. J., Pacific Tel. & Tel. Co., Seattle, Wash.
(Applicant for re-election.)
McFarland, R. H., Tri-State College, Angola, Ind.
McKelvey, D. M., (Member), 60 East 42nd St., New York, N. Y.
Mercier, F. E., Commonwealth Edison Co., Chicago, Ill.
Mettendorff, H. A., Board of Light Commissioners, Westfield, N. Y.
Mikulasek, G. W., Pacific Gas & Elec. Co., Oakland, Calif.
Miller, C. W., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Miller, L. E., Rudolph Wurlitzer Mfg. Co., N. Tonawanda, N. Y.
Milmow, A., (Member), 217 Latonia Bldg., Charlotte, N. C.
Montgomery, J. S., General Railway Signal Co., Rochester, N. Y.
Moschel, M. A., Commonwealth Edison Co., Chicago, Ill.
Moss, G. G., Radio Service & Television Labs., Greeley, Colo.
Murdoch, G. B., Pennsylvania Railroad Co., Philadelphia, Pa.
Murphy, J. L., Graybar Electric Co., Buffalo, N. Y
Murray, F. H., American Tel. & Tel. Co., New York, N. Y.
Nash, H. M., Great Western Power Co., Las Plumas, Calif.
Nelson, C. J., Public Service Co. of No. Illinois, Chicago, Ill.
Newton, W. H., (Member), New York & Queens Electric Light & Power Co., Flushing, N. Y.
O'Keeffe, C. W., Brooklyn Edison Co., Brooklyn, N. Y.
Olsen, E. A., Stone & Webster Engg. Corp., Seattle, Wash.
Orr, J. J., A. J. Brandt, Inc., Detroit, Mich.
Ostaseski, P., General Electric Co., Bloomfield, N. J
Peck, T. A., (Member), Shell Petroleum Corp., St. Louis, Mo.
Perkins, E. A., C. H. Tenney & Co., Boston, Mass.
Perry, J. H., Commonwealth Edison Co., Chicago, Ill.
Pottle, W. R., Dominion Government, Regina, Sask., Can.
Pursell, R. W., Southern New England Tel. Co., New Haven, Conn.
Rawlins, H. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Rimmele, H., Public Service Electric & Gas Co., Newark, N. J.
Robison, H. F., Commonwealth Edison Co., Chicago, Ill.
Roy, J. A., Cambridge Elec. Lt. Co., Cambridge, Mass.
Rubel, M. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Samples, M. E., Commonwealth Edison Co., Chicago, Ill.
Sanders, L. L., Buffalo Niagara & Eastern Power Corp., Buffalo, N. Y.
Schellberg, K. O., Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Scott, W. F., Electrical Shop, Washington, D. C.
Seelye, O. W., Moore & McCormack S. S. Co., New York, N. Y.
Selpien, C. W., Commonwealth Edison Co., Chicago, Ill.
Serduke, J. T., General Electric Co., Schenectady, N. Y.
Seufert, F. L., United Engg. & Construction, Newark, N. J.
Shenk, W. E., United States Steel Corp., New York, N. Y.
Shipley, W. W., Western Electric Co., Baltimore, Md.
Shows, W. G., Commonwealth Edison Co., Chicago, Ill.
Smith, S. M., (Member), Can. Westinghouse Co. Ltd., Fort William, Ont., Can.
Sorensen, A. J., Commonwealth Edison Co., Chicago, Ill.
Speed, R. B., Theodore Roosevelt High School, New York, N. Y.
Stieglitz, S., New York Edison Co., New York, N. Y.
Stojak, L. F., 2511 W. 23rd St., Chicago, Ill.
Streit, F. H., Los Angeles Gas & Elec. Corp., Los Angeles, Calif.
Struven, D. J., J. H. Bunnell & Co., New York, N. Y.
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Terrell, P. A., (Member), Copperweld Steel Co., Birmingham, Ala.
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Timberlake, J. J., American Brown Boveri Electric Co., Camden, N. J.
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Underhill, C. R., Jr., R. C. A. Photophone, Inc., New York, N. Y.
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Watson, C. J., Jr., General Electric Supply Corp., Memphis, Tenn.
Webb, L. W., General Electric Co., Erie, Pa.
Welch, G. H., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
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Wright, M. W., Louisville Gas & Elec. Co., Louisville, Ky.

Total 150.

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Dubash, D. M., Taj Mahal Hotel, Bombay, India
Foard, J. W., Compania Standard Electric, Buenos Aires, Argentine, So. America
Gunawardane, S. T. D., (Member), Elec., Standardizing, Testing & Training Institution, London, Eng.
Hogarth, J. R., General Electric Co., Ltd., Witton, Birmingham, Eng.
Lazo, M., F. A., Andes Copper Mining Co., Potrerillos, Chile, So. America
Reynolds, R. W., Venezuela Gulf Oil Co., Maracaibo, Venezuela, So. America
Rivers, T. H., British Thomson-Houston Co., Rugby, Eng.
Rokkaku, H., Electrotechnical Laboratory, Ministry of Communication, Tokyo, Japan
Wilmot, R. H., College of Technology, Leicester, Eng.

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No. 4—Southern	W. S. Rodman, Box 675, University, Va.	J. S. Miller, Jr., Box 12, University, Va.
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No. 6—North Central	Herbert S.Evans, University of Colorado, Boulder, Colo.	M. S. Coover, University of Colorado, Boulder, Colo.
No. 7—South West	B. D. Hull, Southwestern Bell Tel. Co., Dallas, Tex.	A. E. Allen, 1801 North Lamar St., Dallas, Tex.
No. 8—Pacific	C. E. Fleager, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.	H. W. Hitchcock, 1050 Telephone Building, 740 South. Olive St., Los Angeles, Calif.
No. 9—North West	G. E. Quinan, Box 1879, Seattle, Wash.	J. Hellenthal, Puget Sound Pr. & Lt. Co., Seattle, Wash.
No. 10—Canada	C. E. Sisson, Canadian General Electric Co., 1025 Lansdowne Ave., Toronto, Ont.	W. L. Amos, Hydro-Elec. Power Commission, 190 University Ave., Toronto, Ont.

Note: Each District Executive Committee includes the chairmen and secretaries of all Sections within the District and the chairman of the District Committee on Student Activities.

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Birmingham	(4)	W. E. Bare	O. E. Charlton, Alabama Power Co., Birmingham, Ala.
Boston	(1)	W. H. Colburn	G. J. Crowdes, Simplex Wire & Cable Co., Sidney St., Cambridge, Mass.
Chicago	(5)	T. G. LeClair	F. R. Innes, c/o Electrical World, 7 So. Dearborn St., Chicago, Ill.
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Cleveland	(2)	T. D. Owens	Wm. H. LaMond, Simplex Wire & Cable Co., 2019 Union Trust Bldg., Cleveland, O.
Columbus	(2)	R. A. Brown	C. D. Price, 87 East Blake Avenue, Columbus, Ohio
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San Francisco	(8)	L. F. Fuller	G. Ross Henninger, Electrical West, 883 Mission St., San Francisco, Cal.
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Southern Virginia	(4)	H. C. Leonard	Cecil Gray, Westinghouse E. & M. Co., 912 Electric Bldg., Richmond, Va.
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Iowa, State University of, Iowa City, Iowa	(5)	T. F. Taylor	L. N. Miller	E. B. Kurtz
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Marquette University, 1200 Sycamore St., Milwaukee, Wis	(5)	H. W. Haase	G. C. Reichert	J. F. H. Douglas
Massachusetts Institute of Technology, Cambridge, Mass	(1)	R. H. Swingle	C. M. Twelves, Jr.	W. H. Timbie
Michigan College of Mining and Technology, Houghton, Michigan	(5)	Charles F. Sawyer	B. G. Swart	G. W. Swenson
Michigan State College, East Lansing, Mich	(5)	R. L. Clark	G. A. Whitfield	L. S. Foltz
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Minnesota, University of, Minneapolis, Minn	(5)	R. W. Fenton	W. M. Taylor	J. H. Kuhlmann
Mississippi Agricultural & Mechanical College, A. & M. College, Miss	(4)	W. F. Barksdale	A. H. Peale	L. L. Patterson
Missouri School of Mines & Metallurgy, Rolla, Mo	(7)	George W. Douglas	J. D. Shelton	I. H. Lovett
Missouri, University of, Columbia, Mo	(7)	L. G. Weiser	W. Sevchuk	M. P. Weinbach
Montana State College, Bozeman, Mont	(9)	E. B. Wilson	O. Van Horn	J. A. Thaler
Nebraska, University of, Lincoln, Neb	(6)	V. L. Bollman	W. E. Stewart	F. W. Norris

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New Hampshire, University of, Durham, N. H.	(1)		Carl B. Evans	L. W. Hitchcock
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New York, College of the City of, 139th St. & Convent Ave., New York, N. Y.	(3)	Eugene J. Erdos	F. J. Wodicka	Harry Baum
New York University, University Heights, New York, N. Y.	(3)	N. G. Schutt	T. S. Humphrey	J. Loring Arnold
North Carolina State College, Raleigh, N. C.	(4)	H. W. Horney	E. R. Price	R. S. Fouraker
North Carolina, University of, Chapel Hills, N. C.	(4)	J. J. Alexander	F. R. Toms	J. E. Lear
North Dakota Agricultural College, State College Station, Fargo, N. D.	(6)	R. Stockstad	Robert Carlson	H. R. Rush
North Dakota, University of, University Station, Grand Forks, N. D.	(6)	R. W. Olson	G. E. Glass	H. F. Rice
Northeastern University, 316 Huntington Ave., Boston, 17 Mass.	(1)	R. W. Littlefield	R. J. Edwards	Wm. L. Smith
Notre Dame, University of, Notre Dame, Ind.	(5)	E. G. Conroy	Ben South	J. A. Caparo
Ohio Northern University, Ada, Ohio	(2)	D. Pringle	H. L. Hartman	I. S. Campbell
Ohio State University, Columbus, Ohio	(2)	G. F. Leydorf	R. W. Steenrod	F. C. Caldwell
Ohio University, Athens, Ohio	(2)	Thomas A. Elder	Jess W. Best, Jr.	A. A. Atkinson
Oklahoma A. & M. College, Stillwater, Okla.	(7)	H. V. Anderson	E. F. Neal	Albrecht Naeter
Oklahoma, University of, Norman, Okla.	(7)	E. E. Brady	C. W. Anthony	F. G. Tappan
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Demand Meters.—Catalog GEA-612, 28 pp. Describes the G-E line of standard demand meters, including indicating, graphic and printing types for all classes of service. General Electric Company, Schenectady, N. Y.

Portable Power Units.—Bulletin 14, 4 pp. Describes Century Model D power units for farm applications. These units are built in standard 3, 5 and 7½ hp. sizes and are made to operate on current delivered by any power company. Century Electric Company, 1806 Pine Street, St. Louis, Mo.

Graphic Instruments.—Bulletin AE-830, 8 pp. Describes Roller-Smith graphic instruments, comprising switchboard, wall and portable types, a-c. and d-c. ammeters, voltmeters, single and polyphase wattmeters and power factor meters. Roller-Smith Company, 12 Park Place, New York.

Safeguarding Wire Systems For Buildings.—Bulletin, 16 pp. sets forth the merits of rigid conduit as a means of protection for wiring systems. Typical applications are illustrated. The booklet has been prepared by the Rigid Conduit Section of the National Electrical Manufacturers Association, George H. Sicard, Secretary, 603 Gas & Electric Building, Utica, N. Y.

Condenser Coupling for Power Line Telephony.—Bulletin describes Dubilier type 670 coupling condensers for power line telephony. Capacities, prices, number required in series for different line voltages, and dimensions of the unit are included, as well as a list of prominent users. Dubilier Condenser Corporation, 342 Madison Avenue, New York.

Circuit Breakers.—Bulletin 1872, 8 pp. Describes high-voltage, oil circuit breakers rated at 115,000 to 230,000 volts; Bulletin 1875, 8pp., describes breakers rated at 46,000, 69,000 and 92,000 volts. These bulletins cover a new line of high-voltage circuit breakers, type GO, some of them equipped with Deion grids and conforming to the new N. E. L. A. voltage ratings. Westinghouse Electric & Manufacturing Co., East Pittsburgh, Penna.

NOTES OF THE INDUSTRY

The Allis-Chalmers Manufacturing Company, Milwaukee, Wis., announces the removal of its Chicago District Office to the Civic Opera Building, 20 No. Wacker Drive.

The Belden Manufacturing Company, Chicago, manufacturer of electrical wire, cable and cordage, announces the election of Whipple Jacobs, general sales manager, to the office of vice-president. Mr. Jacobs has been connected with the company since leaving school in 1914.

Additions to Ohio Brass Staff.—S. Murray Jones and F. G. Hart, both of whom were formerly connected with operating companies, have recently joined the power utilities department of the Ohio Brass Company, Mansfield, Ohio. Mr. Jones was previously connected with the Alabama Power Company and Mr. Hart with the Kansas Power & Light Company.

Copperweld Steel Company, Glassport, Penna., announces the appointment of Leslie C. Whitney as chief metallurgist. For the past five years Mr. Whitney has been employed as assistant head of the Physical Laboratories of one of the largest wire manufacturers in the country. Mr. Whitney is now supervising the installation of equipment in the Copperweld Steel Company's new research laboratory.

American Transformer Company Appoints Representatives.—The American Transformer Company, Newark, N. J., manufacturers of radio and industrial transformers, announces the appointment of the Westburg Engineering Company, 53 W. Jackson Blvd., Chicago, and the Electric Apparatus Sales Co., 10 High St., Boston, as sales representatives in the Chicago and and New England sections respectively.

Stevens & Wood, Inc. Merged with Allied Engineers, Inc.—It is announced that the Allied Engineers, Inc. has been organized to take over the assets, business and organizations of Stevens & Wood, Inc., Dixie Construction Company and Empire Construction Company. The new company will be located at 120 Wall Street, New York, about May 1. E. A. Yates, formerly vice-president of the Southeastern Engineering Company, will be Chairman of the Board; B. F. Wood, formerly of Stevens & Wood, Inc., will be president, and W. H. Sawyer, O. G. Thurlow, B. L. Huff, R. W. Stovel and A. C. Polk will be vice-presidents.

Steel and Tubes, Inc., announces the removal of the general sales department of the electrical division from Brooklyn, N. Y., to its general offices at 224 East 131st Street, Cleveland. The personnel is as follows: Morgan P. Ellis, general manager, electrical division; Murray J. Whitfield, general sales manager, electrical division; L. E. Fuller, western district sales manager, Peoples Gas Building, Chicago; James S. Magan, field engineer, Peoples Gas Building, Chicago, Ill. Local representatives are established in numerous cities.

New Master Switch For Cranes.—The Electric Controller & Manufacturing Company, Cleveland, O., announces a new master switch to regulate the control circuits of the magnetic contactor controller and intended for use on cranes, hoists, ore bridges, steel mill machinery and other applications where full speed control from the master switch is desired. The design of the new switch insures smooth and ease of operation due to the use of ball bearings, the short throw of the operating handle, the absence of gears, and the fact that the contact fingers always ride on uninterrupted plane surface.

New Oil Circuit Breaker.—The Pacific Electric Manufacturing Corporation, San Francisco, Cal., announces a new oil circuit breaker, type RW-64, 115 kv., 600 ampere. The new breaker has welded tanks of boiler plate steel. The operating shaft is carried on roller bearings, power being transmitted from this shaft to the rotating vertical shaft by means of bronze bevel gears that are also carried on roller bearings. The rotating member that supports the moving contacts consists of a Bakelite tube having dielectric strength in excess of the requirements of the A. I. E. E. specifications. The Type MW-40 control is equipped with a tripping device that permits very high speed operation. All contacts are shielded to prevent corona loss. The new breakers are furnished for voltages from 92,000 to 230,000. Orders are now on the books of the company for breakers of this design for the entire voltage range including 230,000 volt equipment.